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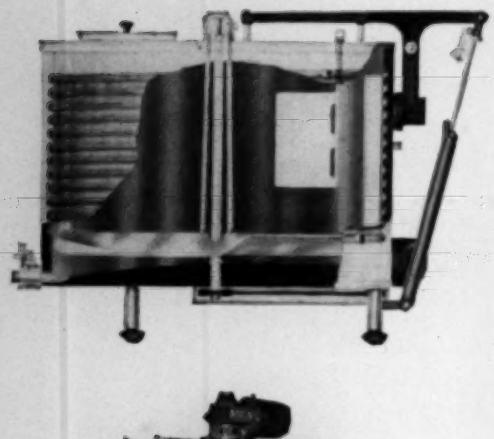

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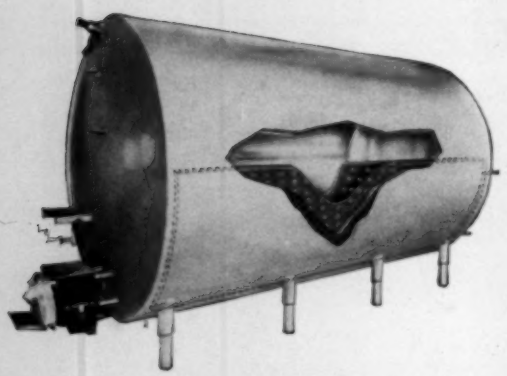

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## EDITORIAL

# Relationships and Similarities of the Pharmaceutical and Food Industries[a]

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(Received for publication, May 29, 1950)

It is interesting to make comparisons between the pharmaceutical and food industries, because a study of the problems indicate both close similarities and wide divergences. We often travel closely parallel paths, and by processes sometimes obscure we have often learned valuable lessons from each other.

If for no other reason, we are alike in the attention we must give to the numerous problems we constantly face relating to public health. Our responsibility to the consumers of our products can never be crowded from our minds by other less worrisome and more attractive considerations.

Many efforts have been made to define clearly what a food is and what a drug is. Some of the attempts have been pretty good. The trouble in framing the definitions has always come at the places where the two meet. Difficulty in this borderline area is to be expected. Today it is this borderline area which interests me most because some of the most enlightening relationships are illustrated there.

We could hardly mention foods and drugs in the same breath without thinking about developments in the vitamin field during the past 30 or 40 years. Two centuries ago the rich, in their ignorance, over-ate on a diet consisting of meats, pastries and wine. The poor, in their poverty, existed on bread, bacon, cheese and beer. Fruits, vegetables and milk entered the diet only gradually and only in comparatively recent times.

On the meat, bread, cheese and beer diet of two centuries ago people began to recognize definite deficiency patterns and the foods which prevent them, but real progress has been made only in our day. Lemon juice for scurvy was prescribed for the British navy in the 18th century. But chemical isolation of vitamin C was not achieved until about 1930. As recently as the 1920's we were talking just of vitamins A, B and C. Then vitamin D was pried loose from fat-soluble vitamin A, and vitamins E and K later made their appearance in the fat-soluble class. Water-soluble vitamin B has blossomed into a complex whose entire nature we have not yet determined. Vitamin C has remained just vitamin C.

Although nutritional experts have done much to educate us to a balanced diet, the sale of vitamins as pharmaceuticals has earned an assured place. Man in these days frequently is a sedentary animal. His caloric requirements, therefore, are often satisfied by three relatively small meals a day, which do not supply an optimal vitamin intake. It is now an established practice to supplement the diet with additional vitamins in pure form or in concentrates purchased from the drug store. The circle is completed by the food industry, which now enriches flour, margarine and other foods with pure vitamins from the factories of the pharmaceutical manufacturer.

Do you remember those days back in the 1920's, too, when hope dawned for those who suffered from pernicious anemia? Raw liver was the answer. If only the patient would eat a half-pound or so of raw liver every day of his life, he would probably get along very well. But, grateful as they were, patients could tolerate such a diet only so long. It was not long before chemists in the laboratories of the meat packers and the pharmaceutical manufacturers had provided relief in the form of a liver extract that could be injected painlessly at convenient intervals.

We have gone along rather well with liver extract these last 25 years. But now the combined efforts of the chemists and the microbiologists have brought us pure crystalline vitamin $B_{12}$. On a weight basis this is the most active physiologic substance known. Again, drug and food scientists are collaborating in this borderline problem, and the mysteries of pernicious anemia and its treatment may soon be a thing of the past. Furthermore, vitamin $B_{12}$ is showing great promise as an important growth factor for both animals and human beings.

The safety of our products in the hands of the ultimate consumer is of concern to all of us. In research in this field the pharmaceutical industry has of necessity had a head start, because so many drugs are foreign to physiological processes; but the food industry is coming along fast. One reason for the time difference has been the difference in legal requirements imposed. Since 1938 we have been accustomed to filing with the Food and Drug Administration new drug applications on all of our new products, with complete data which showed the safety of the drugs in human patients. We have followed a prescribed routine in shipping new drugs only to competent investigators who help us determine safety.

The food industry is just getting to this point. Until just recently it has been illegal, really, for you to ship for experimental purposes across state lines foods containing ingredients not provided for in identity standards. But now, at the instigation of your representatives, the FDA has established a permit system

[a] Presented at the Tenth Annual Meeting of the I. F. T., Chicago, Illinois, May 22, 1950.

by which you may ship these foods for studies such as are carried out on drugs.

By the very nature of the substances which are interesting as drugs, — substances that have high physiological activity, — the pharmaceutical manufacturers have had the safety problem facing them for a long time. It is only now that food manufacturers are meeting these problems with any frequency. More and more chemical ingredients have gained attention as possible food ingredients because of attractive properties—propionates as mold inhibitors in bread, monosodium glutamate for enhancing the flavor of foods, and so on.

The difference in the approach to the problem of safety by the two industries is well illustrated by an experience with a surface-active agent. The chemical manufacturer engaged a pharmacologist to make an extensive study of this type of material in experimental animals. After years of work he concluded that the agent was substantially nontoxic when given by mouth. At this time we became interested in it as a drug because it showed promise of benefiting patients who were unable to absorb dietary fat because of some abnormality of the intestinal tract. When this surface-active agent was taken with the meal, it emulsified dietary fat so that it was readily absorbed by the faulty intestine. On the basis of the toxicity studies carried out by the pharmacologist, we were able to market the material with assurance that it was safe for drug use.

More recently, however, surface-active agents of this same type have attracted attention as softening agents for bread. You are probably all aware, from reports in trade publications, that testimony on this type of ingredient has run to thousands of pages at food standards hearings conducted by the FDA. This points up the difference in the problem as it is faced by our two industries. I do not mean to imply that pharmaceutical manufacturers do not have quite a job on their hands in establishing the safety of drugs. We do. Sometimes we spend years completing the necessary data. But you have an even bigger job. It is the position of the Food and Drug Administration that the scientific work necessary to establish the safety of a food ingredient will usually be more extensive than that necessary to support a new drug application. While a drug will have limited use under certain prescribed conditions, a food ingredient may be used in a wide variety of foods which are consumed in varying amounts by all classes of people in varying stages of health and throughout their life time.

For this reason and for other reasons, some of them unfortunately political, it has been proposed recently that the Food, Drug, and Cosmetic Act should be amended to provide for a new food ingredient application similar to the present new drug application. The proposal merits the most careful consideration to determine its practicability. The ethical firms in the food industry, of course, wish to do everything possible to protect the public health. There is plenty of evidence for this. Witness the quick cooperation given by the food industry in eliminating the use of the Agene process for aging and bleaching flour because of adverse findings in experimental animals, even though no deleterious effects in human beings have ever been demonstrated.

Your industry is now engaged in contributing to the public safety by participation in the FDA hearings on insecticide residues on fresh fruits and vegetables. The amount of time and effort which must go into the presentation of complete data at an extended hearing such as this would be hard to estimate. Nevertheless, I can imagine that you are going to give whole-hearted cooperation to the investigation, so that the necessary safeguards surrounding the use of insecticides on food crops can be established.

Perhaps an illustration can be given of how the pharmaceutical manufacturer must employ restraint where a question of public safety is involved in the use of new chemical substances. For a number of years we have carried on investigations on a new synthetic sweetening agent, with no caloric value. It should be of considerable interest to diabetics and to other patients who must restrict their intake of sugars. It offers two advantages: it has no bitter after-taste, and it does not decompose in boiling solutions. It may therefore be used in cooking and baking. While it is many times sweeter than sugar, it is not nearly so sweet as saccharin.

When extensive toxicity studies had been completed, including feeding the material to three successive generations of mice, feeding it to rats daily for 2½ years, and giving it to dogs for a period of a year, it was concluded that the sweetening agent possessed a remarkably low toxicity. Rather broad clinical tests were then made, aimed at showing whether the material had any unexpected and rare poisonous properties in human beings which could not be foreseen.

After the agent had been cleared both in animal and human tests, we felt that we were justified in using the material in a small way to sweeten some unpalatable pharmaceutical preparations. This introduction of the material was a cautious one, because the preparations in which they were used were administered only in limited doses for a short period of treatment. Following this, we felt we were at last ready to put out the sweetening agent in tablet form for use by patients in their special diets.

The next step is one which crosses the borderline from drugs to foods. This is the biggest step. As you can imagine, a sweetening agent of this type might well be useful in the preparation of certain special dietary foods. Not of ordinary foods such as would be sold in a grocery store, of course, since artificial sweeteners are forbidden in such products by Federal law.

Before we could consider the introduction of the synthetic sweetener into special foods, we wanted to be entirely satisfied that the material is non-toxic. We are now satisfied, and the Food and Drug Administration has publicly stated its agreement, so that the material is considered safe for food use. Incidentally, the time elapsed since the first preliminary investigations were made on the material amounts to nearly 15

years, with some time out, of course, for more important war work.

Perhaps we should turn to another phase of our industrial activity. And in this phase it is the food industry which has taken the lead. I refer to the preservation and stabilization of perishable commodities. The canners have been pioneers in the study of this problem, and probably still know more about it than the drug manufacturers have ever learned. Other food technologists have looked into preservation by means of drying and freezing. In some cases it has been necessary to promote the stability of processed foods by addition of various types of preservatives. All of these techniques which have been developed by food scientists have been adapted by pharmaceutical manufacturers to their own problems and products.

Packaging problems are always with us. The tin plated can has a long and honorable history in the food industry. But more recently special food packaging problems have given rise to many new developments in glass containers, plastic films and coated papers. Drug manufacturers, on the other hand, have so far restricted their packaging largely to glass containers. We are cautiously looking into plastics, and have made a few tentative moves to use them.

Both industries are interested in the best process of killing pathogenic anerobic spore-forming microorganisms in our liquid products. It is at this point that drug people stand in awe of the food processors, who have accumulated data in such detail on the exact temperature and pressure which will safely process practically any food in any type of container of any given size. Along with these figures, you food technologists have picked up an immense amount of know-how on the design and control of processing equipment.

This is a field in which we have borrowed heavily in recent years, particularly since we began to put up in glass containers a variety of solutions to be used by intravenous infusion. Many of the drugs put up in this form are sensitive to excessive heat, to impurities in glass, to certain ranges of pH, and so on. We have adapted much of the food work on the heat killing of *Clostridium botulinum* and *Clostridium sporogenes* to the sterilization of these intravenous infusion solutions.

I would be very much surprised if the food industry were not highly interested in the recent reports on experimental preservation of canned foods with antibiotics which has been carried out at the Western Regional Research Laboratory. Addition of only 10 parts per million of subtilin appeared to be satisfactory for preservation even of non-acid foods used in the trials, thus permitting a quick heat processing step only sufficient to inactivate enzymes.

This promising line of research indicates that we may soon find another close tie between the food and drug industries. I can assure you that the pharmaceutical manufacturer will not mind if you find that you can properly make use of the production of the plants manufacturing antibiotics.

Since the beginning of time, food handlers have been faced with the problem of rancidity of oils and fats. Fortunately, many natural products of this class contain their own antioxidants, which permit their storage for a reasonable time. Technological advances have permitted the preparation of modified products such as hydrogenated oils, which themselves are then less susceptible to oxidation. However, there has been a continuing need for more effective antioxidants. Among agents of natural origin, oat flour has now been used broadly for a number of years. And more recently prolonged toxicity studies by the Food and Drug Administration and others have made it possible for the Bureau of Animal Industry to issue regulations permitting the use of a number of synthetic antioxidants, such as butylated hydroxyanisole, propyl gallate and esters of thiodipropionic acid.

Drug manufacturers have been aware to some extent that there is a similar stability problem with the fat-soluble vitamins A and D. However, I hardly think their consideration of the matter has generally gone as far as you have gone in stabilizing food fats and oils.

While we are speaking of the stabilization of foods and drugs, we might return for a minute to the surface-active agents. Druggists 15 years ago had few emulsifying agents which would permit them to put oily materials into a water base. Among them were lanolin, various gums and soap. With their help the druggist was able to make an ointment or a cod liver oil emulsion that was not objected to because it was the best there was.

In the last 12 years or so we have suddenly been deluged with a great variety of surface-active agents which permit an elegant job of emulsification that had not previously been thought of. We now have nicely flavored homogenous, aqueous dispersions of vitamins A and D which are almost entirely transparent. We also have stable suspensions of finely powdered procaine penicillin in water which are capable of producing prolonged penicillin blood levels with only a single injection.

In our daily lives we experience the benefits which food scientists have afforded us by the proper use of emulsifiers. No longer does the housewife expect to be spattered with hot fat from the frying pan, now that sulfated stearyl monoglycerides are incorporated into frying fats. Shortenings are easily creamed into cake batter, and in fact with surface-active agents there have been prepared the wide variety of cake, pie and biscuit ready-mixes to which the housewife needs only to add water.

Both of our industries experience enough change to keep things more than just interesting. As one would expect, there is competition between products from natural and synthetic sources, and sometimes the competition takes on the characteristics of a pendulum. It has certainly been true in the drug industry since the days of World War I. Before that time, of course, most drugs were of natural origin. But then along came the work of the great German chemist, Ehrlich, who developed a synthetic drug for syphilis. The impetus of this discovery was great and has never been lost.

During the 1920's and early 1930's, even though synthetic drug research was moving rapidly, scientific biologic research also progressed rapidly and brought

forth a large number of vaccines, antisera and bacterins which were invaluable in medical practice of the time. However, when the sulfa drugs were developed in the middle thirties, they were so specific and so effective against a number of serious microbial diseases that the pendulum swung far over to the synthetic side. For a few years we thought of almost nothing else—the future was bound to be in the field of highly active, highly specific synthetic organic drugs.

Then you know what happened. The pendulum suddenly took the most violent swing of all, and there we were with the best drug that had ever happened, a natural drug named penicillin. More of these antibiotics have come along since, and more will come in the future. But as it is, we now recognize that both nature and the chemical laboratory have a place in our scheme of things, and we look for good future drugs from both directions.

You in the food industry face similar, constantly changing situations. Most apparent to the outsider just now is the competition facing animal by-products. As a matter of fact, we in pharmaceutical manufacturing still feel very dependent on animal by-products. What drugs in the past year have received more publicity than cortisone and ACTH for rheumatoid arthritis? At present both drugs are derived from animal by-products.

We are all aware that synthetic materials have entered into the fields formerly monopolized by animal hides. Lard and hydrogenated lard are threatened, it is said, by synthetic emulsifiers in bakery products. We are very familiar, too, with the long-standing competition between butter and oleomargarine as they face each other in a common market.

There are conflicting impulses in our hearts regarding changes that take place in industry. There is the tendency to sympathize with the established manufacturer who has a good thing. We want to see him keep it. On the other hand, we sympathize with the newcomer who has developed a good thing. We want to see him make good with it. I think we can all agree that competition conducted on a fair basis is good for us all.

Although my acquaintance with food research is not great, I strongly suspect that the same principles guide its organization in your field that do in the drug industry. There is a certain amount of applied research directed toward the immediate improvement of products already on the market, or the improvement of manufacturing processes for them. There are those long months and years of carrying the food product from the laboratory to full-scale production. Then there is the devotion of a certain amount of effort to what the universities would call pure research—that is, research which is not directed toward any narrow end, but toward seeing what will turn up when intelligent investigators follow interesting leads.

In this last type of research, I might say that, to me, the principle of serendipity is most important. Serendipity, as you know, is the ability to find something valuable when you are looking for something else. Both the food and drug fields have provided many excellent examples. There is the "Brown 'n' Serve" baking formula that was discovered recently by a baker in Florida, an intelligent observation that may be revolutionizing the industry. There is the discovery of the potent antiepileptic action of Tridione, a drug which was first made and used as a pain-killer and which only months later was intelligently studied by a pharmacologist and seen to have utterly unsuspected possibilities in the treatment of epilepsy.

Have I belabored the subject enough? With a little thought we could easily collect much more evidence that the similarities of the food and drug industries are ample to justify our working together more often than we do now. Let's keep the way open for exchanging ideas. It will benefit us both in our efforts to promote the welfare of the American public.

# The Preparation and Storage of Freestone Peach Juice and Nectar[a,b]

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(Received for publication, June 18, 1950)

**The possibilities of using blends of peach juice with peach puree to produce nectars has been investigated. Some such nectars show consistency and flavor qualities superior to those of the clear peach juice.**

The tremendous increase in production and sale of fruit juices in recent years has come about as a result of the demand for the high quality products. While it is likely that citrus, grape, pineapple, and tomato juices will continue to be the most important, it seems that there should be a demand for palatable fruit drinks prepared from some of the other fruits such as cherries, strawberries, raspberries, and peaches.

Several reports have been published on the preparation and pasteurization of such juices, and the changes which occur in them during storage *(1, 2)*. While juices from most of the other fruits were found to be acceptable, the juice or nectar from freestone peaches

[a] Journal paper No. 830, New York State Agricultural Experiment Station, Geneva, New York.

[b] Presented at the Tenth Annual Meeting of the I. F. T., Chicago, Illinois, May 24, 1950.

was not entirely satisfactory. Efforts to improve the latter product are described in this paper.

In some of the earlier studies, attempts were made to obtain satisfactory products from peaches by various methods, as hot and cold extractions, pressing and pulping, and the use of antioxidants. However, it was not until the following methods were developed, that an acceptable product was made. First, the color and flavor of peaches could be retained by blanching, cooling, and freezing, using ascorbic acid on the surface of the peaches. Second, it was found that a good yield of excellently flavored juice could be obtained by pressing fruit which had been frozen at 15° F. (—9.4° C.) and later thawed. A blend of the pressed juice so obtained with a pureed product resulted in a smooth textured, palatable nectar that retained the peach flavor characteristics.

A study has been made of this type of product to determine the proportions of pressed juice and pureed fruit necessary to give the most desirable texture and flavor. Further, since some juices have a limited storage life, it seemed desirable to store these products at different temperatures over a period of a year to note changes in color, flavor, ascorbic acid (vitamin C) and carotene (provitamin A) content.

## Methods

In these studies, fruit harvested in 1945, 1946, 1948, and 1949 was used. The procedure found most suitable for preparing the peaches was to steam blanch fully ripened halved peaches for three minutes, followed by cooling, peeling, and packing in 30-pound enameled tins, adding a teaspoonful of ascorbic acid to the surface of the peaches. This is equivalent to approximately 40 mg. of ascorbic acid to 100 grams of fruit. The fruit was then frozen at 15 to 18° F. (—9.4 to —7.8° C.). After freezing, the cans were transferred to the 0° F. (—17.8° C.) room and held there until they were needed for processing. A part of these peaches were made into a clear juice by thawing and pressing in an ordinary hydraulic press, and the remainder into a pureed product by milling. For this latter purpose, a Fitzpatrick comminutor with No. 1 screen was used. It should be realized, however, that the results may differ with another type of mill or different size screen, particularly in regard to texture and proportion of pressed and milled juices.

Preliminary experiments in 1945 with Elberta peaches showed that a nectar of promise can be made by mixing clear juice with a peach puree. The yellow varieties Halehaven, Elberta, and Crawford, and the white variety Champion were used in 1946. Pressed juices only were studied. Elberta peaches were used in 1948 and 1949 for continued study of nectars because of their commercial production in quantity in this area, and since the flavor of this variety carries through to the final product. A peach variety which lacks flavor or has a very mild flavor could hardly be expected to yield the most desirable product. Five percent of sugar was added to juices. The quantity of sugar required may vary from year to year because of differences in acid and total sugars in the fruit used. It was found that the sugar could be added either at the time when the peaches were peeled for freezing or to the juice during processing.

The juice obtained from each variety was divided into two parts for storage tests. One-half of the juice was not pasteurized while the other half was heated to 170° F. (76.7° C.). The samples of both raw and pasteurized juices to be held in frozen storage were filled into pint bottles, nine-tenths full, to allow for expansion during freezing. These were stored at 15 to 18° F. (—9.4 to —7.8° C.) and at 0° F. (—17.8° C.). Pasteurized juices for storage at 34° F. (1.1° C.) and 70° F. (21.1° C.) were filled full in pint bottles, capped, cooled, and stored. Storage studies were carried out to determine changes in flavor, color, and ascorbic acid content at the different temperatures.

Yields as high as 72.6 percent juice were obtained by pressing the frozen and thawed fruit. This juice was blended with pureed fruit in varying proportions. The most satisfactory blend or nectar was one containing 25 percent puree and 75 percent juice. This product was milled again after blending and deaerated cold *(4)*. However, it was found necessary to deaerate it a second time in the cold, and a third time after heating to 160° F. (71.1° C.). This gave a smooth blend from which at least the greater share of the tissue gases had been removed. Sugar was added to the extent of 2.5 percent, and the nectar was then pasteurized at 180° F. (82.2° C.), filled into 12-ounce bottles, capped, and cooled. Bottles to be stored at freezing temperatures were, of course, filled only nine-tenths full. This nectar was stored at 0, 18, 34, 45, and 70° F. (—17.8, —7.84, +1.1, +7.2, and 21.2° C.). This product was very good but rather viscous.

In view of this viscosity, blends of juice and puree were prepared in 1949, containing 5, 10, 15, 20, 25, and 30 percent of puree. Preference tests with the original juice and the blends showed that the 15, 20, and 25 percent levels of puree were the most pleasing, the preference in texture leaning toward the lower and in flavor toward the higher amounts of puree. However, this is a matter of individual choice and it is obvious that a commercial processor would be obliged to determine the texture desired on the basis of consumer preference.

## Analytical Methods

The juices were analyzed for ascorbic acid by the xylene extraction method of Robinson and Stotz *(5)* and for total carotene by using the foaming mixture method, followed by adsorption on a column *(3)*. Clear juices such as prepared in the 1946 series were not analyzed for carotene because it was obvious that only insignificant amounts of this substance could be present. Color density was determined with a Beckman Spectrophotometer at a wave length of 400 mμ, using 1 cm. cells.

## Results

Taste tests (using a score of 1 for the poorest up to 10 for the best) indicated that Champion peaches give the best flavored clear juice (Table 1). Elberta gives a very satisfactory product under proper conditions of storage. Of the four varieties, Halehaven yielded a juice which was relatively inferior, probably because of its mild flavor. Juices stored at room temperature and those unpasteurized juices stored at 0° F. (—17.8° C.) were rated somewhat lower than the other juices. It seems odd that the unpasteurized juices stored at 0° F. (—17.8° C.) should rate lower than those stored at 18° F. (—7.8° C.).

TABLE 1

*Average Flavor Panel Scores of Four Peach Juices After One Year's Storage*

| Peach variety | Pasteurized juice stored at | | | | Raw juice stored at | |
|---|---|---|---|---|---|---|
| | 70° F. | 34° F. | 18° F. | 0° F. | 18° F. | 0° F. |
| Elberta | 5.2 | 7.0 | 5.6 | 6.4 | 5.8 | 5.0 |
| Champion | 6.4 | 6.8 | 7.0 | 6.7 | 6.8 | 6.2 |
| Crawford | 6.1 | 6.3 | 6.7 | 6.0 | 6.3 | 5.4 |
| Halehaven | 4.8 | 5.1 | 6.8 | .... | 6.0 | 2.4 |

While the flavor scores show that the clear juice is acceptable as a product provided it has been properly prepared and stored, it was obvious that some improvement would be desirable. Nectars prepared in the 1948 series which were blends of juice and puree were clearly superior.

Samples of the nectar when stored for a year at all storage temperatures used showed only slight losses of ascorbic acid and carotene (Table 2) and they were

TABLE 2

*Ascorbic Acid and Carotene Content of Elberta Peach Nectar After One Year's Storage at Different Temperatures*

| Vitamin | Original juice | Pasteurized juice stored at | | | | |
|---|---|---|---|---|---|---|
| | | 70° F. | 45° F. | 34° F. | 18° F. | 0° F. |
| Ascorbic Acid, mg. per 100 ml. | 21 | 16 | 18 | 15 | 19 | 20 |
| Carotene, mg. per 100 ml. | 27 | 34 | 31 | 28 | 31 | 32 |

rated higher by the taste panel than the original juice samples. Average taste panel score for the product stored at 70° F. (21.1° C.); 45° F. (7.2° C.); 34° F. (1.1° C.); 18° F. (—7.8° C.) and 0° F. (—17.8° C.) were 5.1, 7.3, 7.8, 6.8, and 6.4 respectively. The nectars stored at the highest temperature were significantly poorer in flavor.

No significant changes in ascorbic acid content of peach juice occurred during storage (Table 3), except

TABLE 3

*Ascorbic Acid Content of Ascorbic Acid—Fortified Raw and Pasteurized Peach Juice Stored at Different Temperatures*

| Peach variety | Ascorbic Acid Content, mg. per 100 ml. | | | | | | |
|---|---|---|---|---|---|---|---|
| | Immediately after processing | Month's storage | Pasteurized juice stored at | | | | Raw juice stored at | |
| | | | 70° F. | 34° F. | 18° F. | 0° F. | 18° F. | 0° F |
| Elberta | 47 | 6 | 46 | 48 | 46 | 47 | 45 | 46 |
| | | 12 | 43 | 53 | 51 | 52 | 50 | 50 |
| Champion | 31 | 6 | 27 | 29 | 31 | 30 | 32 | 28 |
| | | 12 | 28 | 32 | 32 | 33 | 35 | 32 |
| Crawford | 23 | 6 | 19 | 20 | 21 | 21 | 20 | 20 |
| | | 12 | 16 | 20 | 20 | 23 | 17 | 21 |
| Halehaven | 29 | 12 | 21 | 25 | 26 | 29 | 25 | 27 |

in those samples stored at room temperature. In these lots only the juices made from Halehaven and Crawford showed drops which might be considered greater than the experimental error.

In the 1946 peach juice, significant increases in optical density occurred during storage at room temperature (Table 4). At other storage temperatures,

TABLE 4

*Changes in Optical Density at 400 mμ of Peach Juice During Storage*

| Peach variety | Optical density | | | | | | |
|---|---|---|---|---|---|---|---|
| | Month's storage | Pasteurized juice stored at | | | | Raw juice stored at | |
| | | 70° F. | 34° F. | 18° F. | 0° F. | 18° F. | 0° F. |
| Elberta | 0 | 0.41 | ..... | ..... | ..... | ..... | ..... |
| | 6 | 0.43 | 0.39 | 0.38 | 0.38 | 0.38 | 0.39 |
| | 12 | 0.45 | 0.43 | 0.43 | 0.41 | 0.40 | 0.40 |
| Champion | 0 | 0.30 | ..... | ..... | ..... | ..... | ..... |
| | 6 | 0.37 | 0.32 | 0.30 | 0.32 | 0.26 | 0.27 |
| | 12 | 0.44 | 0.34 | 0.35 | 0.38 | 0.32 | 0.32 |
| Crawford | 0 | 0.28 | ..... | ..... | ..... | ..... | ..... |
| | 6 | 0.40 | 0.31 | 0.31 | 0.31 | 0.25 | 0.24 |
| | 12 | 0.47 | 0.51 | 0.35 | 0.31 | 0.33 | 0.30 |
| Halehaven | 0 | 0.25 | ..... | ..... | ..... | ..... | ..... |
| | 6 | 0.32 | 0.26 | 0.26 | 0.26 | 0.24 | 0.24 |
| | 12 | 0.40 | 0.30 | 0.32 | 0.30 | 0.30 | 0.26 |

however, these changes were less, and may have been due almost entirely to the physical changes which occur during storage rather than to a true color difference as was obvious in the samples stored at room temperature.

## Summary

The consistency, flavor, and ascorbic acid characteristics of the juices from four peach varieties were analyzed during storage at different temperatures. The clear juice from the Champion peach rated highest in flavor of the varieties tried.

A blend or nectar of peach juice and puree containing 15 to 25 percent of the latter, prepared from frozen Elberta peaches, was found to be a desirable product. The ascorbic acid and carotene contents of peach nectar were found to show little change on storage in the frozen state for one year.

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# Control of Enzymatic Flocculation of Cloud in Citrus Juices

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**The nature of the "cloud" in citrus juices is discussed in detail. Apparently there are several enzymes involved in the loss of "cloud" in unheated citrus juices. These enzymes must be inactivated in order to enhance the stability of citrus juices and of concentrates. The application of a previously described test to ascertain the expected stability of "cloud" in a citrus juice is discussed in view of recent processing developments in the citrus products industry.**

Prior to about 1927, the carbonated beverage industry in the United States utilized practically no citrus juice as such in the production of orange and lemon sodas. These bottled carbonated drinks were by tradition brilliantly clear liquids composed essentially of carbonated water, sugar, citric acid, flavor and appropriate certified color. One large distributor of carbonated beverage did incorporate orange juice in his product for several years prior to 1927 but inasmuch as this component was clarified it did not contribute materially either to the appearance or the flavor of the beverage.

Laboratory work and trial sales campaigns at that time indicated that the carbonated beverage industry in many parts of the country would not accept products made from natural, or cloudy citrus juices. This resistance was due largely to the fact that the natural cloud forming constituents of the beverage would settle, leaving a clear or nearly clear supernatant liquid, and forming a layer of sediment in the bottom of the bottle. This was particularly objectionable to consumers who generally considered the presence of insoluble matter in clear beverages as an indication of spoilage or contamination. Bottlers also complained of the insoluble solids clogging various parts of the bottling equipment, and of the unsightly appearance of the beverages in display racks.

The first attempt to overcome these difficulties involved the use of gravity separation to remove the coarser insoluble solids. The juice was partially concentrated and then stored in tall cylindical tanks to allow the coarser particles to settle. The supernatant liquid, containing only the finely divided suspended materials, was used to prepare the final concentrate. This procedure was only partially successful in that flocculation of the finely divided insoluble solids frequently occurred before the concentrated juice was used by the bottler.

At about this time work was started on the development of a cloud stabilization process *(13)* based on the now well known scheme of pectic enzyme inactivation by high temperature pasteurization.

This process has become widely used not only in the manufacture of concentrated juices for preparation of beverage bases but also in the canning industry. Descriptions of some phases of flash pasteurization, as applied to the citrus industry, have appeared in the literature *(1-8, 10-12, 15)* but except for brief patent disclosures *(13, 14)* none of the work of this laboratory has been published.

Some of this earlier work is reviewed herein, particularly if the work has application in the present stages of citrus products manufacture.

Citrus juices extracted by the commonly used methods contain considerable quantities of insoluble solids, usually referred to as suspended matter. The amount of the material varies according to the method of extraction, screening, filtering, or centrifuging employed in the preparation of the juice. The insoluble matter varies in size from the very small pigmented bodies to the coarser bodies such as juice sacs, or fragments of juice sacs, section coverings, albedo, and the like. The relative proportions of the different size particles depend upon the method of extraction and screening.

When well deaerated fresh juice stands for a few hours, a sharp line of demarkation is generally obtained between the coarse and the more finely divided insoluble particles. The coarse material or pulp settles out and forms a loose layer in the bottom of the container. In the absence of enzyme action, settling of the finer particles is slower, and months may be required for substantial clearing of the juice. This material, which remains in more or less permanent suspension, is referred to as the cloud of the juice. Since most of the cloud is composed of pigmented material, it is also responsible in a large part for the characteristic color and general appearance of the juice. The cloud also carries much of the flavor of the juice and is therefore very important from this standpoint.

The insoluble matter in fresh juice is uniformly dispersed and may remain in this condition until destabilization is brought about by pectic enzyme action. The settling of the coarse insoluble solids may progress to completion, leaving a good cloud in the supernatant liquid, before enzymic flocculation of the cloud starts. When flocculation begins, the whole mass of cloud may appear to coagulate or precipitate simultaneously and settle out leaving the supernatant liquid clear or nearly so. In other cases a veil seems to form at the top of the liquid and slowly falls, carrying the cloud with it. In juices containing much pulp, the whole suspended pulp mass may form into a solid jelly, with separation of clear liquid at the top and sides of the container. With less pulp content the pulp may settle to the bottom before forming into a jellied mass. Some juices do not show enzymic flocculation even after long periods of storage at ordinary temperatures.

The theory of the enzymic flocculation of cloud is that the dispersed pectin, which in its natural state serves to stabilize the finely divided insoluble matter, is reduced in molecular size and partially demethoxylated by pectic enzyme action so that it becomes sensitive to the natural calcium and other salts of the juice. When sufficient pectin (and calcium) is present the pectin is converted to a solid gel. When small amounts of pectin are present the end products appear as a precipitate rather than as a gel. The finely divided insoluble solids are occluded in the gel or precipitate and carried down with it. The pectin in the coarser insoluble matter is affected in the same way but the action here probably serves more to increase the firmness of the particles than to occlude the cloud.

The earliest observations of the behavior of cloud in citrus juices prepared and handled in different ways were most perplexing. As may be seen in Table 1, raw juices extracted by different methods, with varying opportunity for contact with peel constituents, and with

TABLE 1

*The Effect of Storage Temperature on the Time Required for Flocculation of Samples of Raw Orange and Lemon Juices (Samples Preserved with 0.25 Percent Sodium Benzoate)*

| Sample Number | Citric Acid (Anhydrous), percent | pH | Time Required for Flocculation at Different Temperatures, Days | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | | | 2° C. | 10° C. | 20° C. | 28° C. | 37° C. | 50° C. | 60° C. |
| Orange 1 | 1.10 | 3.79 | 5.4 | ..... | 3.4 | 1.5 | 2.0 [a] | 12.0 [a] | 7.3 [a] |
| Orange 2 | 1.09 | 3.80 | 2.0 | ..... | 0.8 | 0.8 | 1.8 [a] | 5.2 [a] | 5.7 |
| Orange 3 | 1.10 | 3.79 | 5.1 | 4.5 | 4.5 | 12.0 [a] | 9.5 | 34.0 [a] | 10.0 [a] |
| Orange 4 | 1.00 | 3.84 | 6.3 [a] | 13.0 [a] | 71.0 [a] | 179.0 [a] | 51.0 [a] | 107.0 [a] | 20.0 [a] |
| Orange 5 | 0.95 | 3.85 | 20.0 [a] | 52.0 [a] | 61.0 [a] | 151.0 [a] | 20.0 [a] | 17.0 [a] | 59.0 [a] |
| Orange 6 | 1.13 | 3.78 | 3.3 | 2.8 [a] | 26.0 [a] | 33.0 [a] | 24.0 [a] | 60.0 [a] | 53.0 |
| Orange 7 | 1.10 | 3.79 | 5.9 | 4.0 [a] | 1.8 | 1.9 [a] | 2.2 [a] | 9.3 [a] | 12.0 [a] |
| Orange 8 | 1.27 | 3.65 | 84.0 [a] | 58.0 [a] | 115.0 [a] | 125.0 [a] | 58.0 [a] | 105.0 [a] | 35.0 [a] |
| Orange 9 | 0.83 | 3.88 | 6.0 | 4.9 | 3.5 | 4.4 [a] | 4.8 | 72.0 [a] | 10.0 [a] |
| Orange 10 | 0.92 | 3.93 | 4.2 [a] | 2.8 | 2.1 | 1.8 | 1.9 | 4.8 [a] | 5.1 [a] |
| Orange 11 | 0.81 | 3.93 | 4.5 | 4.2 [a] | 5.2 [a] | 10.0 [a] | 7.8 [a] | 11.0 [a] | 5.2 [a] |
| Orange 12 | 1.01 | 3.84 | 9.5 | 5.5 | 3.2 | 2.2 [a] | 1.9 | 4.3 [a] | 10.0 [a] |
| Orange 13 | 0.99 | 3.88 | 7.9 | 4.9 | 3.0 [a] | 1.9 | 1.2 | 2.3 | 6.3 [a] |
| Orange 14 | 1.13 | 3.78 | 3.3 | 2.8 | 26.0 | 33.0 | 24.0 | 60.0 | 53.0 |
| Lemon 1 | 6.11 | 2.43 | 29.0 [a] | ..... | 3.2 [a] | 2.0 [a] | 2.1 [a] | 60.0 [a] | 29.0 [a] |
| Lemon 2 | 5.45 | 2.40 | 10.0 [a] | 96.0 [a] | 17.0 [a] | 12.0 [a] | 4.1 [a] | 53.0 [a] | 14.0 [a] |
| Lemon 3 | 5.51 | 2.39 | 9.5 [a] | 62.0 [a] | 17.0 [a] | 11.0 [a] | 3.5 [a] | 52.0 | 14.0 [a] |

[a] These samples retained from a slight to considerable haze even after the flocculation process appeared to be completed. All others were brilliantly clear.

different final pulp contents were very erratic with respect to the tendency for cloud flocculation. Some samples flocculated within a few days and showed a consistent relationship between flocculation time and storage temperature, while others required up to 179 days for complete flocculation and showed no consistent relationship between flocculation time and storage temperature. The most rapid flocculation and the most consistent relation between flocculation time and storage temperature were obtained with juices containing relatively large amounts of pulp.

Reamer-extracted orange juice containing a relatively large amount of pulp, when acidified with citric acid or buffered with sodium citrate to different pH values and stored at different temperatures, showed a fairly consistent relationship between flocculation time and storage temperature. This is shown in Series I of Table 2. Juice prepared by crushing whole fruit between corrugated rolls (Series II), with pulp removal by first passing the juice through a reel type screen and then through a centrifuge, was very inconsistent in its behavior when treated and stored in the same way.

Further tests were made with these same two types of juices by first pasteurizing at different temperatures and then storing each sample at different temperatures, as shown in Table 3. The burred juice was again the most consistent in its reaction to storage temperature and to pasteurization temperature (Figure 1).

It will be observed that the flocculation rate of the burred juice, Series I, was decreased by pasteurization at temperatures as low as 122° F. (50° C.), particularly with 37.4° F. (3° C.) storage. The effect of the heat treatment progressively increased with increase in pasteurization temperature up to 158° F. (70° C.), with no further change at 176° F. (80° C.). The other type of juice, Series II and III, was less consistent in its reactions, for reasons that will be evident later, but even in this case a marked effect was evident from pasteurization at 158° F. (70° C.), with 37.4° F. (3° C.) storage.

This was the first evidence that orange juice contains either two pectin esterases, or possibly an esterase and an activator, and that one of the enzymes, or the activator, is inactivated by pasteurization at some temperature between 140 and 158° F. (60 and 70° C.) *(13)*. This was further indicated by adding pectin to a series of samples of juice pasteurized at different temperatures and determining the rate of demethoxylation at pH 6.5 by the method of Kertesz *(9)*.

The studies made to determine the conditions that influence the rate and completeness of flocculation of raw natural strength juice indicate that a number of

TABLE 2

*The Effect of pH and Storage Temperature on the Rate of Flocculation of Orange Juice (Samples Preserved with 0.25 Percent Sodium Benzoate)*

| Series | Sample Number | Citric Acid (Anhydrous), percent | pH | Time Required for Flocculation at Different Temperatures, Days | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | | | | 2° C. | 10° C. | 20° C. | 28° C. | 37° C. | 50° C. | 60° C. |
| I | 1 | 0.95 | 4.48 | 3.0 | 2.2 | 1.8 [a] | 0.8 | 1.1 | 1.2 [a] | 2.1 [a] |
| | 2 | 0.96 | 4.17 | 4.4 | 2.6 | 1.5 | 0.9 | 0.8 [a] | 0.9 [a] | 1.5 [a] |
| | 3 | 0.96 | 3.92 | 6.3 | 4.5 | 2.6 | 1.5 | 1.3 | 1.2 | 5.0 |
| | 4 | 1.47 | 3.58 | 3.9 | 2.5 | 1.5 | 1.1 [a] | 1.1 [a] | 2.6 [a] | 10.0 [a] |
| | 5 | 2.47 | 3.18 | 3.9 | 2.5 | 1.1 [a] | 2.2 [a] | 2.9 [a] | 5.4 [a] | 12.0 [a] |
| | 6 | 3.46 | 2.95 | 2.8 [a] | 2.8 [a] | 3.9 [a] | 8.9 [a] | 6.9 [a] | 12.0 [a] | 24.0 [a] |
| | 7 | 4.46 | 2.77 | 5.4 [a] | 3.9 [a] | 13.0 [a] | 8.9 | 5.0 [a] | 12.0 [a] | 12.0 [a] |
| II | 1 | 1.25 | 4.59 | 191 [a] | 84 [a] | 49 [a] | 35 [a] | 22 [a] | 105 [a] | 58 |
| | 2 | 1.27 | 4.19 | 85 [a] | 48 [a] | 39 | 25 [a] | 12 [a] | 106 [a] | 43 |
| | 3 | 1.27 | 3.96 | 58 [a] | 43 | 36 | 32 [a] | 13 [a] | 105 [a] | 43 |
| | 4 | 1.27 | 3.65 | 84 [a] | 58 [a] | 115 [a] | 125 [a] | 58 [a] | 105 [a] | 35 [a] |
| | 5 | 1.78 | 3.39 | 152 [a] | 152 [a] | 174 [a] | 132 [a] | 93 [a] | 132 [a] | 35 |
| | 6 | 2.52 | 3.09 | >200 | >200 | >200 | >200 | 200 | 93 [a] | 58 |
| | 7 | 3.79 | 2.82 | >200 | >200 | >200 | >200 | 93 [a] | 98 [a] | 26 [a] |
| | 8 | 5.73 | 2.49 | >200 | >200 | >200 | 66 [a] | 29 [a] | 84 [a] | 22 [a] |

[a] These samples retained from a slight to considerable haze even after the flocculation process appeared to be completed. All others were brilliantly clear.

TABLE 3

*The Effects of Pasteurization and Storage Temperature on the Rate of Flocculation of Orange Juice (Samples Preserved with 0.25 Percent Sodium Benzoate)*

| Series | Sample Number | Citric Acid (Anhydrous), percent | pH | Pasteurization Temperature ° C. [b] | Time Required for Flocculation at Different Temperatures, Days | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | 3° C. | 10° C. | 20° C. | 28° C. | 38° C. | 52° C. | 62° C. |
| I | 1 | 0.99 | 3.88 | none | 7.9 | 4.9 | 3.0 | 1.9 | 1.2 | 2.3 | 6.3 [a] |
| | 2 | 0.99 | 3.88 | 50.0 | 13.0 | 7.1 | 4.1 [a] | 2.4 | 1.5 | 4.1 [a] | 7.0 [a] |
| | 3 | 0.99 | 3.88 | 60.0 | 30.0 [a] | 17.0 | 8.3 [a] | 4.6 [a] | 2.7 | 3.5 | 7.0 [a] |
| | 4 | 0.99 | 3.88 | 70.5 | 40.0 [a] | 35.0 [a] | 30.0 | 22.0 [a] | 13.0 [a] | 9.3 | 7.0 |
| | 5 | 0.99 | 3.88 | 80.0 | 40.0 [a] | 35.0 [a] | 30.0 | 22.0 | 13.0 [a] | 9.3 | 7.0 |
| II | 1 | 1.13 | 3.78 | none | 3.3 | 2.8 [a] | 26.0 [a] | 33.0 [a] | 24.0 [a] | 60.0 [a] | 53.0 |
| | 2 | 1.13 | 3.78 | 50.5 | 5.9 [a] | 6.8 [a] | 29.0 [a] | 95.0 [a] | 62.0 [a] | 142.0 [a] | 60.0 |
| | 3 | 1.13 | 3.78 | 60.4 | 10.0 | 7.2 [a] | 4.9 [a] | 27.0 [a] | 130.0 [a] | 42.0 [a] | 66.0 [a] |
| | 4 | 1.13 | 3.78 | 70.5 | 35.0 [a] | 31.0 | 13.0 [a] | 11.0 [a] | 9.9 [a] | 14.0 [a] | 18.0 [a] |
| | 5 | 1.13 | 3.78 | 80.0 | 36.0 [a] | 31.0 | 13.0 | 10.0 [a] | 6.3 | 19.0 [a] | 26.0 [a] |
| III | 1 | 1.10 | 3.79 | none | 5.9 | 4.0 [a] | 1.8 | 1.9 [a] | 2.2 [a] | 9.3 [a] | 12.0 [a] |
| | 2 | 1.10 | 3.79 | 50.5 | 8.8 [a] | 6.3 [a] | 2.5 | 2.2 [a] | 3.3 [a] | 13.0 [a] | 16.0 [a] |
| | 3 | 1.10 | 3.79 | 60.4 | 18.0 | 12.0 | 5.1 | 3.3 [a] | 2.9 | 9.2 [a] | 11.0 [a] |
| | 4 | 1.10 | 3.79 | 70.5 | 38.0 [a] | 30.0 [a] | 15.0 | 12.0 [a] | 9.3 | 7.3 [a] | 8.0 [a] |
| | 5 | 1.10 | 3.79 | 80.0 | 38.0 [a] | 30.0 [a] | 15.0 | 7.3 | 6.9 | 7.3 [a] | 8.0 [a] |

[a] These samples retained from a slight to considerable haze even after the flocculation process appeared to be completed. All others were brilliantly clear.
[b] One minute holding time.

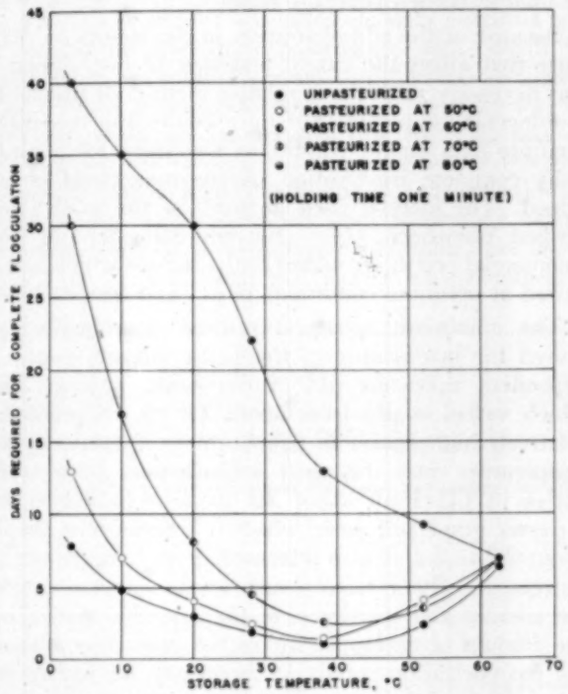


FIG. 1. The effect of storage temperature on the time required for complete flocculation of cloud in natural strength burred orange juice pasteurized at different temperatures.

factors are involved. The most important of these are the amount of pectic enzyme, soluble pectin, the calcium and related salts in the juice, the pH of the juice, and the storage temperature. The amounts of the first three substances are determined by the extent of maceration of the pulpy part of the orange in extracting the juice, the time of exposure of the juice to the pulp before screening, and the extent of removal of pulp in screening. The maturity and condition of the fruit are also of importance. The pectic enzymes seem to be associated with the pectin bearing insoluble solids and consequently the extent of maceration and the amount of pulp left in the juice may have a marked effect on the enzyme content. The calcium is also contained mainly in the pectin bearing part of the pulp. The soluble or dispersed pectin content of the juice is influenced by the pH of the juice and the opportunity given for acid and possibly enzymatic hydrolysis of the pulpy part of the fruit. The pH of the juice is important in another respect, in that it influences the rate of flocculation.

Because of great variation among different juices of the factors that influence the rate of flocculation, the effect of pH could not be exactly determined. Under reasonably favorable conditions the rate of flocculation does not vary greatly over the pH range of about 2.8 to 3.8. The rate decreases rather sharply with lower pH, particularly within the range for lemon juice. As the concentration of enzyme is decreased by pasteurization or other means, the process becomes more sensitive to pH as well as to the other factors. From the data obtained in developing an accelerated flocculation test, using juices in which a substantial amount of the enzymes had been inactivated by pasteurization, it appears that the optimum pH for the process lies between about 2.8 and 3.3, with storage temperature of about 113° F. (45° C.). The optimum pH shifts up or down as the temperature is raised or lowered from this value.

A complication in determining the relation between pH and rate of flocculation is that acid hydrolysis alone appears to be capable of causing changes in pectin which result in a flocculation similar, if not identical, to that caused by enzyme action. This chemical process is accelerated by low pH and high temperatures making it particularly operative in lemon juice.

When raw orange juice is concentrated by the conventional methods, a number of changes occur that affect the rate of flocculation. The concentrations of enzyme, pectin and salts are increased and the pH may be lowered to a somewhat more favorable range. These changes accelerate flocculation and greatly increase the tendency for gel formation at ordinary temperatures. If the concentration is carried high enough, some of the juice constituents increase in concentration sufficiently to have retarding effects. Excessive total soluble solids, titratable acidity, and sodium and potassium salts are definitely inhibitive in action. In case of concentrated lemon juice the increased acidity is the most important inhibitive factor.

Some raw juices flocculate completely when concentrated to 30-60° Brix with the conventional batch evaporators which may require as long as 12 hours for completion of a batch. By careful preparation of the juice to keep the enzyme, calcium, pectin, and pulp contents low, the tendency for flocculation is decreased. Pasteurization at 149-158° F. (65-70° C.), with 1 minute holding time, to inactivate part of the enzyme system also is of value in controlling flocculation.

The soluble solids of juice do not have any appreciable effect on the rate of flocculation until raised to about 45° Brix. The effect increases progressively with increased concentration above this point. With partially stabilized juices or juices relatively low in enzyme content, the effect becomes significant at 60 to 65° Brix. By lowering the pH of the juice to cause true pectin-sugar-acid gel (jelly) formation at 65° Brix, further retardation of flocculation can be obtained.

In using pasteurization to inactivate the pectin enzyme system in citrus juices, two methods may be employed. If the juice is to be frozen and kept in this condition, it is not necessary to completely inactivate the pectic enzymes and consequently a low temperature stabilization process may be used. If the juice is to remain stable under all storage conditions and for all uses, it is necessary to use the high temperature process.

It has been the general practice in the manufacture of frozen juice products to use raw or unpasteurized juice. The reason for this is that pasteurization is generally considered to impair the fresh flavor and nutritive value of the juice and with certain types of juice to materially lighten the color.

When frozen natural strength citrus juice is stored at temperatures as low as —10° F. (— 23.3° C.), complete flocculation may occur within a few days. The rate and completeness of flocculation can be influenced by proper juicing, screening, and handling methods, as discussed above, but it is not feasible to control flocculation entirely in this way. Proper screening is important in another way, in that high pulp content leads to the development in California orange juice of an off taste that has been described as "straw" taste. Peculiarly, frozen 42° Brix concentrated juice has been found to be less subject to flocculation than natural strength juice.

In earlier manufacture of frozen natural strength orange juice it was found that flocculation of the insoluble solids could be controlled satisfactorily by pasteurizing the juice at about 149° F. (65° C.), with about 1 minute holding time. This seems to be about the minimum requirement but in commercial practice slightly higher temperatures, as 149-158° F. (65-70° C.), were used because of lack of precision control of the pasteurization process. This process has been used successfully with 42° Brix concentrated juice in laboratory studies.

The pasteurization conditions necessary to effect low temperature stabilization coincide rather closely with the minimum conditions necessary to destroy spoilage organisms.

The amount of damage to the flavor of juice caused by pasteurization is determined to a considerable extent by the method of preparing, screening and handling of the juice. Entrapped air and, in general, increased pulp content contribute to flavor damage. The type and method of operation of the pasteurizer may also be important.

Raw frozen juice is practically always superior in initial flavor to pasteurized frozen juice. In comparative tests with natural strength juice containing considerable pulp, most tasters considered the pasteurized product as equal or preferable in flavor, after six to twelve months of storage. Because of destruction of enzymes or some other change, pasteurized juice deteriorates more slowly during storage than raw juice.

Whenever citrus juices are to be stored in the nonfrozen state substantially complete inactivation of the pectic enzyme system usually must be effected to be certain that enzymatic flocculation of cloud will not occur. This is particularly true of products that are to be used in bottled beverage bases.

Because of the wide variation in the factors of citrus juice that affect the extent and rate of flocculation, it was necessary to devise a reliable method of measuring the flocculation potential of juice before any reasonably accurate data on the conditions necessary for substantially complete inactivation of enzymes could be obtained. The method used in much of the work is described elsewhere *(14)*. Barium chloride and pure commercial pectin are added to the sample which is then stored at optimum conditions of pH and temperature.

The minimum temperature-time combination required for inactivation of the pectic enzyme system is dependent upon the pH of the juice. Orange juice which varies in pH from about 3.3 to 3.8 requires a relatively high minimum temperature. A relatively low temperature may be used with lemon juice which varies in pH from about 2.2 to 2.4. California and Arizona grapefruit juice which is intermediate in pH, about 2.7 to 3.2, is also intermediate in temperature requirement. Other factors such as the enzyme content, the amount and coarseness of the insoluble matter, and the amount of entrapped air in the juice also influence the pasteurization conditions necessary for satisfactory inactivation of the enzyme system.

There is a minimum temperature for each pH below which it is not feasible to go without extending the holding time to unreasonable limits. This temperature for orange juice of pH 3.8 is about 189° F. (87° C.). At this pH satisfactory stabilization of orange juice, deaerated and of average pulp content, may be accomplished at 192° F. (89° C.) with holding time of about 2 minutes. By raising the temperature to about 201° F. (94° C.) the holding time may be decreased to 15 seconds. At pH 3.3 the temperatures required with these two holding times are about 185 and 194° F. (85 and 90° C.), respectively. The corresponding temperatures for grapefruit juice of pH 3.2 and lemon juice of pH 2.4 are 183 and 192° F. (84 and 89° C.), and 156 and 165° F. (69 and 74° C.), respectively.

The curves in Figure 2 show what is considered to be the minimum pasteurization temperature required with one and two minute holding times to obtain satis-

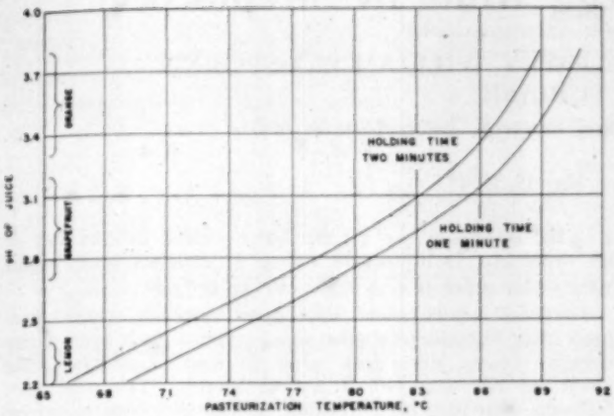


FIG. 2. Trend curves representing minimum temperature required to provide satisfactory inactivation of pectic enzymes in natural strength citrus juices of different pH.

factory stabilization of cloud over the pH range of 2.2 to 3.8. These curves are based on data obtained with a continuous laboratory pasteurizer with which the pasteurization conditions could be controlled accurately. The residual flocculation potential of the juice was determined with an accelerated test method, also by determining the behavior of the juice under the most favorable commercial conditions for flocculation of cloud. The results obtained with individual batches of orange juice at three different pH values are shown in Figure 3. The lower pH values were obtained by

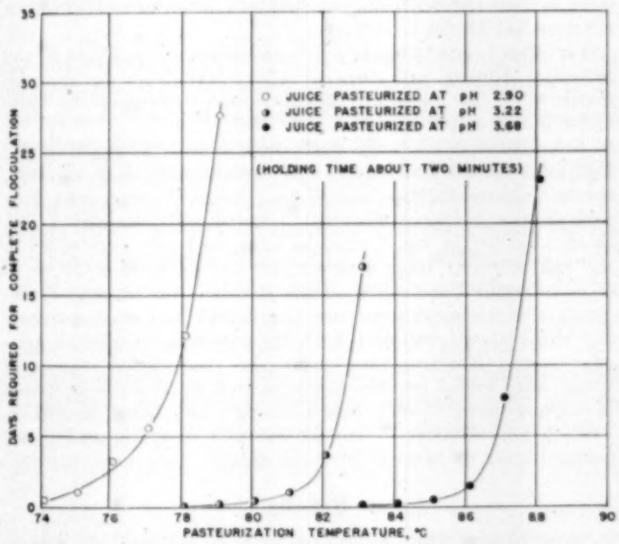
JUICE PASTEURIZED AT pH 2.90
JUICE PASTEURIZED AT pH 3.22
JUICE PASTEURIZED AT pH 3.68
(HOLDING TIME ABOUT TWO MINUTES)
DAYS REQUIRED FOR COMPLETE FLOCCULATION
PASTEURIZATION TEMPERATURE, °C

FIG. 3. The effect of pH on the pasteurization requirements to stabilize the cloud of burred orange juice. Flocculation time was determined by an accelerated test in which 20 days' stability indicates commercially satisfactory juice.

adding citric acid to the juice. The juices of these series requiring 20 days or longer for flocculation by the test method used were considered as satisfactorily stabilized. The effect of holding time in the pasteurization of lemon juice is shown in Figure 4. Samples of this series that required 4 days or longer for flocculation were considered as satisfactory in stability.

In commercial operation it is considered desirable to keep the holding time within the range of about 0.25 to

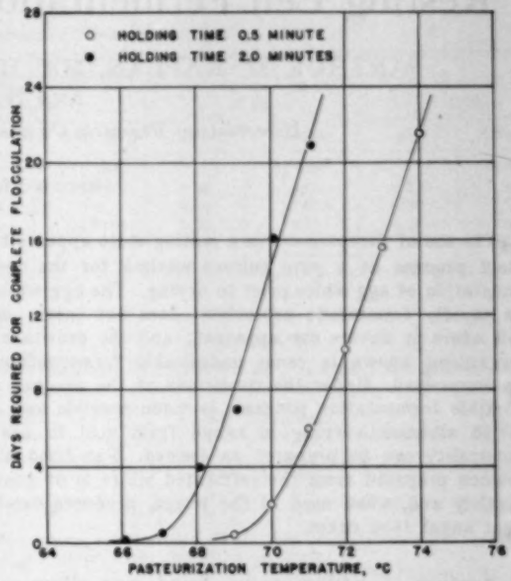
HOLDING TIME 0.5 MINUTE
HOLDING TIME 2.0 MINUTES
DAYS REQUIRED FOR COMPLETE FLOCCULATION
PASTEURIZATION TEMPERATURE, °C

FIG. 4. The effect of pasteurization temperature on the inactivation of pectic enzymes in burred lemon juice (pH 2.3). Flocculation time was determined by an accelerated test in which 4 days' stability indicates commercially satisfactory juice.

2 minutes and employ the lowest temperature that will insure satisfactory results with the particular operating conditions used. A rapid and reliable method of testing for residual active enzyme is essential for controlling such a commercial process.

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# Resting Cell Fermentation of Egg White by Streptococci[a]

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**The use of Streptococci in a resting state appears to hold promise as a pure culture method for the fermentation of egg white prior to drying. The egg white is rapidly fermented; proteolysis does not occur; no off odors or flavors are apparent; and the growth of organisms known to cause undesirable fermentations is suppressed. Under the conditions of the process, a flexible fermentation program is made possible and a dried albumen varying in range from acid to near neutrality can be prepared as desired. Pan-dried albumen prepared from the fermented white is of good quality and, when used in the recipe, produces excellent angel food cakes.**

Production of edible-grade, dried egg albumen has been hampered by the variable results obtained when egg white is "spontaneously" fermented prior to drying. In an effort to obtain satisfactory fermentations, pure culture techniques have been proposed *(1, 2, 4, 5, 15)* but have not been generally adopted by the industry. Failure to suppress growth of undesirable microorganisms, poor quality of the fermented white, presence of odors or flavors foreign to egg white, and the nature of the microorganisms themselves from a sanitary point of view are some of the reasons given for the reluctance to use pure culture fermentations. Apparently the foregoing objections are surmounted and certain advantages gained when a resting cell fermentation, using *Streptococci*, is employed. The experimental work described below presents the details of the process *(7)* and its advantages as shown by laboratory-scale fermentations.

## Procedures and Methods

*Streptococci* used in this study were *Streptococcus liquefaciens* 4533,[c] *Streptococcus lactis* L-21,[c] and *Streptococcus lactis* 7963.[d] The strains were routinely carried in aseptically harvested egg white, adjusted to pH 6.8, or in semi-solid trypticase soy agar. Master stock cultures were prepared according to the freeze-drying method of Raper and Alexander *(10)* with trypticase soy agar as the culture medium and sterile skim milk as the suspending medium.

Concentrates of *Streptococci* for seed were prepared from 18 to 24 hour tryptose-phosphate or, preferably, trypticase soy broth cultures by the filtration technique of Kaplan and Elberg *(6)* and later by centrifugation in a Sharples super centrifuge.[e] The former technique yielded pastes containing on the order of $1.3\times10^{12}$ organisms per g.; the latter yielded concentrates on the order of $2.5\times10^{11}$ organisms per g. Original broth counts were on the order of $2.3\times10^{8}$ to $7.0\times10^{8}$ per ml.

Bacterial counts, other than gram negative counts, were made after 48 hours incubation using trypticase soy agar. Gram negative counts were made after 24 hours incubation using violet red bile agar plus 1 percent sucrose. The pour plate technique was used for all counts. Incubation temperature was 30° C. (86° F.) for *Streptococcus lactis*, 37° C. (99° F.) for *Streptococcus liquefaciens*, and 37° C. (99° F.) for gram negative organisms.

Reducing sugars were determined by the colorometric method of Somogyi *(11, 12)* and Nelson *(9)* while nonprotein nitrogen was determined as described by Hawk, Oser, and Summerson *(3)*. Both determinations were made with a Klett-Summerson photoelectric colorimeter fitted with a No. 54 filter. Hydrogen-ion concentration determinations were made with a Beckman pH meter and glass electrode. Formol nitrogen was determined by electrometric titration *(8)* with the Fisher titrimeter.

Egg white for the fermentation studies was for the most part commercially frozen white purchased on the open market in 30-pound tins and held at —26° C. (—15° F.) until used. Freshly broken-out egg white was used in certain instances as indicated. The amount of egg white fermented varied from 100 ml. to 9,000 ml. Normal lactic acid was used to adjust the pH of the egg white prior to fermentation, and whipping tests were carried out according to standard procedure *(16)* with a Kitchen Aid Model G Mixer.

Fermented egg whites were pan-dried in a Proctor and Schwartz 10-tray pan drier at 120° F. (49° C.) to approximately 6 percent moisture. Moisture was determined by overnight drying at 100° C. (212° F.) *(16)*.

Angel food cakes were made with the following formula: Egg albumen (reconstituted to 87 percent moisture) 1¼ cups, cream of tartar 1¼ tsp., salt ¼ tsp., sugar 1½ cups, cake flour (sifted once before measuring) 1 cup, vanilla extract 1 tsp., almond extract ¼ tsp. Cream of tartar and salt were added to the egg white at room temperature and beaten for 10 to 20 seconds at the third speed of the Kitchen Aid mixer. Three-quarters of a cup of sugar was then added in 4 equal portions, and the beating continued until the meringue reached a soft-peak stage. The remaining sugar and flour, sifted together 2 times, were folded into the meringue in 4 equal portions, placed in an ungreased 10-inch tube cake pan, and baked at 375° F. (191° C.) for ½ hour. The cake was then cooled in an inverted position prior to removal from the pan.

## Results

Preliminary investigations in this laboratory with a number of strains of *Streptococci* revealed that the rate of fermentation of egg white varied with the size of the inoculum added as a broth culture. The practical time reduction, however, was limited by the increasing broth contamination of the egg white with increased inoculum size. Through the use of bacterial concentrates it was possible to increase the inoculum to any desired concentration and to appreciably decrease the time of fermentation without contaminating the egg white with broth. Fermentation was thus attained within 2 hours under optimum conditions of temperature and inoculum size (Table 1). In addition, when taken up in an equal weight of saline and held at 4° C. (39° F.), concen-

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[a] Presented before the Tenth Annual Meeting of the I. F. T., Chicago, Illinois, May 23, 1950.

[b] One of the Divisions of the Bureau of Agricultural and Industrial Chemistry, Agricultural Research Administration, U. S. Department of Agriculture.

[c] Obtained from Dr. R. A. Tittsler, Bureau of Dairy Industry, U. S. D. A.

[d] Obtained from the American Type Culture Collection, Washington, D. C.

[e] Mention of this and other products and equipment does not imply Department of Agriculture endorsement or recommendation over other products of similar nature not mentioned.

TABLE 1

*Fermentation of Egg White By Concentrated Streptococci* [a]

| Incubation time (hours) | Inoculum Size (percent) | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | 0.10 | | 0.25 | | 0.50 | | 0.75 | | 1.00 | |
| | pH | Glucose | pH | Glucose | pH | Glucose | pH | Glucose | pH | Glucose |
| | | *percent* | | *percent* | | *percent* | | *percent* | | *percent* |
| 0 | 9.10 | .332 | 9.10 | .364 | 9.00 | .320 | 8.95 | .331 | 8.75 | .348 |
| 1 | 8.70 | .272 | 8.40 | .320 | 8.00 | .256 | 7.50 | .180 | 6.90 | .144 |
| 2 | 8.50 | .274 | 7.50 | .219 | 6.85 | .130 | 6.30 | .032 | 6.15 | .005 |
| 3 | 8.00 | .269 | 6.95 | .159 | 6.50 | .056 | 6.20 | .005 | ..... | ..... |
| 4 | 7.70 | .224 | 6.90 | .102 | 6.20 | .029 | ..... | ..... | ..... | ..... |

[a] Incubation temperature: 37° C. (99° F.). Organism used: *Streptococcus lactis.*

trated *Streptococci* maintained their viability for at least 28 days (Table 2) with no loss of fermentative ability.[f]

The "natural" fermentation of egg white has been shown to be accompanied by an increase in bacterial population *(14)*. In this laboratory, studies with graded inocula of concentrated *Streptococci* demonstrated an increase in total and gram negative counts when small inocula were used and when the fermentation was correspondingly slow. The use of small inocula for the fermentation also appeared to stimulate the growth of gram negative organisms (Table 3) and was often accompanied by off flavors and odors. With optimum inocula and rapid fermentation, however, no increase in total bacterial count and no development of off flavors and odors were observed. Optimum inocula of concentrated *Streptococci* inoculated into sterile egg white *(15)* showed no increase in numbers during the course of the fermentation (Table 4). When inoculated into egg white contaminated simultaneously with 0.5 ml. each of a 24-hour broth culture of *Aerobacter cloacae, Proteus vulgaris, Serratia marcescens,* and *Pseudomonas sp.* or into egg white contaminated with a suspension of chicken feces, no increase in either total or gram negative count was observed nor any off odors or flavors noted (Table 5).

TABLE 2

*Viability of Concentrated Streptococcus lactis When Stored At 4° C. (39° F.)* [b]

| Storage Period | Viable Count (per g. concentrate) |
|---|---|
| 0 | $5.0\times10^{11}$ |
| 8 | $5.0\times10^{11}$ |
| 28 | $5.9\times10^{11}$ |

[b] Concentrate suspended in equal weight of saline.

[f] Rapid fermentations have been obtained with a suspension stored for 80 days. The initial count of this suspension was not available but the count at 80 days was $6.5\times10^{11}$ organisms per g. This count is within the range obtained with fresh concentrates (Table 2).

TABLE 4

*The Fermentation of Egg White by Streptococci in a Resting State* [j]

| Time (hours) | Bacterial Count (per ml.) | pH | Glucose, percent | N.P.N., mg.-percent | Formol Nitrogen, mg.-percent |
|---|---|---|---|---|---|
| 0 | $5.0\times10^{9}$ | 8.60 | .320 | 14.50 | 80.22 |
| 1 | $5.0\times10^{9}$ | 6.30 | .066 | | |
| 1.5 | $5.0\times10^{9}$ | 6.20 | .006 | 18.50 | 79.52 |

[j] Incubation temperature: 37° C. (99° F.). Inoculum: 1 percent by weight. Organism used: *Streptococcus lactis.*

TABLE 5

*The Fermentation of Contaminated Egg White by Concentrated Streptococci* [k]

| Incubation time (hours) | Total Bacterial Count (per ml.) | Gram Negative Count (per ml.) | Glucose, percent | pH |
|---|---|---|---|---|
| 0 [l] | <100 | <100 | .424 | 6.80 |
| 0 [m] | $4.7\times10^{9}$ | $9.2\times10^{8}$ | .310 | 7.10 |
| 1 | $4.7\times10^{9}$ | $3.9\times10^{8}$ | .027 | 5.38 |
| 4 | $4.0\times10^{9}$ | $5.5\times10^{8}$ | .022 | 5.39 |
| 5 | $1.4\times10^{9}$ | $5.3\times10^{8}$ | .026 | 5.38 |

[k] Incubation temperature: 37° C. (99° F.). Inoculum size: 1 percent by weight.

[l] Bacterial count prior to addition of microorganisms.

[m] Bacterial count after addition of *Streptococcus liquefaciens,* and gram negative contaminants.

The fermentation of egg white by optimum inocula of concentrated *Streptococci* appears, therefore, to be brought about by *Streptococci* in a resting state and results in the suppression of the gram negative contaminants stated to cause undesirable fermentations.

Optimum fermentation of egg white by *Streptococci* was found to occur over the temperature range of 26° C. (79° F.) to 37° C. (99° F.), while final pH of the product varied from pH 5.6 to 6.5 depending on the initial pH adjustment (Table 6). It is thus possible to ferment egg white at its natural pH with no acidification, if desired. No significant proteolysis, as evidenced by nonprotein nitrogen and formol nitrogen determinations, occurred during the course of fermentation (Table 4), and the fermented egg white showed no browning when held at 120° C. (248° F.) for 2 hours *(13)*.

TABLE 3

*Bacterial Population Changes In Egg White Seeded With Small Inocula of Concentrated Streptococci* [i]

| Inoculum (percent by weight) | Total Viable Count (per ml.) | | | Gram Negative Count (per ml.) | | | Glucose (percent) | | |
|---|---|---|---|---|---|---|---|---|---|
| | 0 hrs. | 4 hrs. | 24 hrs. | 0 hrs. | 4 hrs. | 24 hrs. | 0 hrs. | 4 hrs. | 24 hrs. |
| Uninoculated | $2.0\times10^{3}$ | $1.6\times10^{4}$ | $5.5\times10^{4}$ | 25 | 45 | $1.9\times10^{4}$ | .362 | .360 | .360 |
| .05 | $4.0\times10^{5}$ | $1.2\times10^{7}$ | $9.0\times10^{7}$ | 10 | 30 | $5.2\times10^{7}$ | .366 | .344 | .054 |
| .15 | $1.5\times10^{6}$ | $1.2\times10^{7}$ | $5.9\times10^{7}$ | 40 | 60 | $2.2\times10^{6}$ | .370 | .298 | .005 |
| .30 | $2.8\times10^{6}$ | $6.0\times10^{6}$ | $1.2\times10^{8}$ | 10 | 120 | $6.5\times10^{5}$ | .370 | .290 | .005 |
| .50 | $8.0\times10^{6}$ | $1.0\times10^{8}$ | $3.5\times10^{7}$ | 25 | 20 | $1.6\times10^{6}$ | .358 | .206 | .005 |

[i] Incubation temperature: 37° C. (99° F.). Egg white adjusted to pH 6.8 prior to fermentation. Organism used: *Streptococcus liquefaciens.*

TABLE 6

*Effect of Temperature and Initial pH on the Fermentation of Egg White by Streptococci in a Resting State* [a]

| Incubation Temperature | Time (Hours) | Sample 1 | | Sample 2 | | Sample 3 | |
|---|---|---|---|---|---|---|---|
| | | pH | Glucose, percent | pH | Glucose, percent | pH | Glucose, percent |
| 26°-28° C. | 0 | 7.00 | .339 | 7.50 | .381 | 9.00 | .311 |
| | 1 | 6.40 | .221 | 7.00 | .208 | 8.05 | .231 |
| | 2 | 6.00 | .109 | 6.40 | .104 | 7.50 | .090 |
| | 3 | 5.60 | .023 | 5.95 | .005 | 6.60 | .036 |
| | 4 | ..... | ..... | ..... | ..... | 6.50 | .008 |
| 37° C. | 0 | 7.00 | .311 | 7.50 | .381 | 9.00 | .355 |
| | 1 | 6.30 | .147 | 6.30 | .133 | 7.15 | .163 |
| | 2 | 5.60 | .005 | 6.00 | .005 | 6.60 | .005 |
| | 3 | 5.60 | .005 | 6.00 | .005 | 6.45 | .005 |

[a] Inoculum: 1 percent by weight. Organism used: *Streptococcus lactis*.

The fermented dried white war readily reconstituted and gave a clean breaking, even textured 6½-inch whip when beaten under standard conditions. When used in angel food recipes, cakes excellent in all respects were obtained as judged by an independent taste panel for appearance, aroma, texture and consistency, flavor, and acceptability (Figure 1).

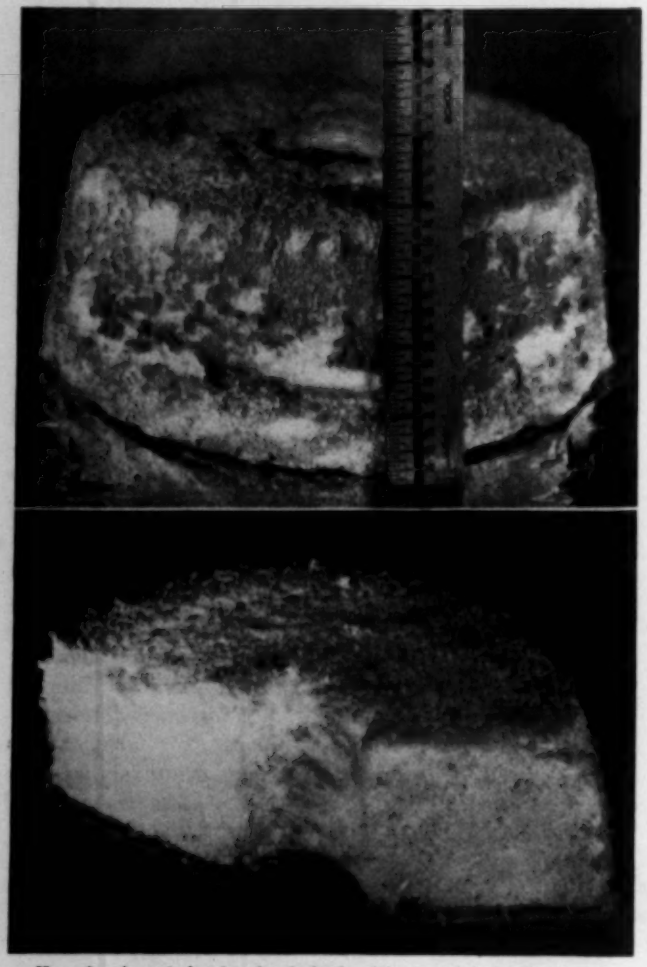

FIG. 1. Angel food cake baked with pan-dried albumen fermented by concentrated *Streptococci* prior to drying.

## Discussion and Summary

The use of *Streptococci* in a resting state appears to hold promise as a pure culture method for the fermentation of egg white prior to drying. *Streptococcus lactis*, the organism of choice, is considered nontoxic and noninfectious, is not a gas producer, does not cause proteolysis of egg white, and, under the conditions of the process, produces a rapid fermentation free of objectionable odor or flavor. The temperature range over which the process can be carried out, 26° C. (79° F.) to 37° C. (99° F.), is wide, while albumen varying in pH from 5.6 to 6.5 can be produced at will. The necessity, inconvenience, and cost of attempting to neutralize acid egg white is thereby obviated if a near-neutral white is desired, since fermentation of egg white at its natural pH results in a final pH of 6.5. The dried albumen prepared from egg white fermented in this manner has the same pH after reconstitution as it had prior to drying.

The use of bacterial concentrates for the fermentation eliminates contamination of egg white by broth constituents and does away with the preparation of mother cultures of egg white with all the attending microbiological hazards of contamination associated with such preparations. Since concentrates can be held for a relatively long period without loss of viability, prepared seed can be held in stock until such time as it is convenient for the fermentation to be initiated. A flexible fermentation program is thereby made possible.

The use of microorganisms in a resting state, as described, results in an extremely rapid fermentation with suppression of the microorganisms shown to be responsible for "off" fermentations.

Application of the process to industrial usage awaits the results of evaluation studies now being conducted under commercial conditions.

## Acknowledgment

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# Bacterial Fish Spoilage and Its Control[a]

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**A REVIEW**

**It is generally accepted that the changes occurring in fish flesh, which lower its palatability and consequently its consumer acceptance, are caused primarily by bacterial action. It is also accepted that the flesh of healthy, live fish is sterile, but that soon after death bacteria begin to invade the muscle tissues from the surface slime and intestinal contents where they occur in large numbers. Recent studies on the effects of temperatures near the freezing point upon fish spoilage bacteria and their activity have emphasized their psychrophilic nature.**

**The main avenues of controlling the bacteria responsible for fish spoilage, namely the reduction of the initial contamination and the inhibition of bacterial growth and activity, are under investigation in various countries. The first is achieved by means of improved sanitary methods of handling fish aboard vessels and in fresh fish plants. In the achievement of the second, the most important single factor, low storage temperature, is emphasized through improved construction of vessels' holds and more effective methods of stowage and shipping.**

## Introduction

The term spoilage is a relative one. The changes which befall the fish flesh between the death of the fish and the time it is completely spoiled may be gradual and assessable, but the point in this chain of successively changing conditions at which the fish flesh is considered no longer palatable, may vary widely with individuals. Opinion may be influenced by the individuals' geographical location, race, customs and eating habits. In Scandinavian countries, for example, some housewives buy only live fish at the local fish market, to assure perfect sea-freshness. Elsewhere, particularly in inland regions, many people have become used to and accept certain changes in the flavor of sea fish which can no longer be associated with perfect sea-freshness. It is also well known that many far-eastern people, in order to make their monotonous, tasteless rice diet more palatable, will flavor it with fermented fish sauces which to our palate are quite foreign if not unacceptable. But even in our own part of the world some fishery products, such as marinated fish and anchovies fillets, are often preferred after they have undergone a certain amount of ripening. We must remember, however, that such products, on account of their rich flavor, are usually not eaten as staple foods, but rather as a seasoning or an appetizer.

Without further elaborating this aspect of varied flavor preferences, let us concentrate on the initial changes from freshness to early spoilage and their effects upon the palatability of what is commonly known as fresh or wet marine fish.

## Sea-Freshness

For meat and game a certain amount of aging is desirable, but for fish, such as cod and haddock, taste panel tests have shown that the freshest fillets, i.e. those cut from fish still in rigor, have the highest palatability rating *(5)*. Cod fillets stored at 32° F. (0° C.) for only one day were found to have already lost some of their most desirable sea-fresh flavor. Of interest is that these changes were noticeable in tasting and smelling the cooked fish flesh before any difference could be demonstrated chemically or organoleptically in the raw fillets. It would be a great exaggeration to conclude from this that fish which have been stored in ice for a number of days are no longer palatable. Yet, the rapid loss of the sea-fresh flavor is a plausible explanation of the fact that fish consumption by populations living near the sea shores, where sea-fresh and nearly sea-fresh fish may be obtained, is often two to four times as high as it is far inland where many people may be entirely ignorant of the real sea-fresh qualities of marine fish.

## Initial Changes: Rigor

Why does sea-freshness disappear so soon? We know that tissues, immediately upon death, are attacked by the autolytic enzymes of both the muscles and the intestinal glands, and later those of the bacteria which may invade the tissues.

[a] Presented before the Tenth Annual Meeting of the I. F. T., Chicago, Illinois, May 23, 1950.

It is generally agreed that autolytic processes account for the initial changes, externally noticeable as rigor mortis, involving transformation of the muscle glycogen to lactic acid with a lowering of the pH to about 6.6 to 6.2. The onset and duration of rigor have been found to vary with different species: Onset at 35.5 to 37.5° F. (2 to 3° C.) in mackerel occurring in a few minutes, in flatfish in 10 hours to mention the two extremes *(15)*. They also depend to a large extent upon the amount of struggling of the fish immediately before death. Trawler caught fish and fish struggling before death go into rigor more quickly and the rigor is of shorter duration than for handlined fish. Low storage temperature during rigor and a low pH will also prolong its duration. A low pH as 5.5 is usually found in flatfish, e.g. halibut *(8)*, and may explain why flatfish keep better, and why they are sometimes preferred when 2 to 3 days old.

Bacterial spoilage of the tissues does not set in until the rigor has been resolved. In order to delay bacterial spoilage of fish flesh, it is therefore of advantage to delay the onset as well as the resolution of rigor.

### Bacteriological Activity

It is also agreed that the changes brought about by autolytic agents, in the non-fatty fishes at least, are rather negligible as compared with the changes caused by bacterial action, in spite of the fact that the flesh of healthy live fish is sterile. Pieces of aseptically cut cod fillets from fresh fish have been held under almost aseptic conditions at 41° F. (5° C.) for 4 to 5 weeks before the first signs of spoilage were noticed *(1)*. On the other hand, pieces of fish flesh cut from gutted cod, held in crushed ice up to 16 days, were found to be completely spoiled although still sterile. Spoilage in this case was due to the diffusion of fish spoilage products from the surface, where the bacterial action took place, into the flesh *(6)*.

The sources of bacterial contamination of the fish flesh are the intestinal contents, the slime covering the fish and dirty surfaces with which fish come into contact on the deck and in the holds of fishing vessels and in the fish plants. A thorough review of the qualitative and quantitative bacteriological aspects of marine fish and fish spoilage has been published recently by Reay and Shewan *(15)*.

Among the bacterial flora of sea fish, our interest is centered on those types which are able to grow and bring about undesirable changes of quality under circumstances usually occurring in the fresh fish industry, i.e. at ice temperatures. Total bacterial counts have their value in indicating sanitary conditions in the vessels or plant and, to a limited extent, future keeping quality prospects of the fish at the time of examination. On the other hand, a specific count of those bacteria which are able to reduce at ice temperatures the trimethylamine oxide of fish flesh to trimethylamine, would provide us with much more accurate information in judging the keeping quality of the fish, especially of non-fatty fish. Bacterial numbers as such have little meaning until they are translated into bacterial activity of specific kind.

### Reduction of Trimethylamine Oxide

It has been shown by a number of workers that marine fish flesh contains trimethylamine oxide, the amounts of which vary with different species and within a species according to season and locality. It has also been demonstrated that this substance can be reduced to trimethylamine by certain bacteria, the responsible enzyme being a specific one, triamine-oxidease *(16)*. It is generally agreed that trimethylamine and dimethylamine production are measurable processes which can be closely related to organoleptic tests of incipient and advancing fish spoilage *(5, 9)*, in non-fatty marine fishes at least. Considerable work has been done also with herring. Furthermore, comparatively easy and rapid laboratory tests have been developed which allow such spoilage to be followed not only in the research laboratory but also in the plant control laboratory.

The trimethylamine production occurs parallel with the bacterial conversion of the lactic acid to acetic and other volatile acids. Proteolysis does not become important until spoilage is well advanced *(1)*.

Trimethylamine determinations are most valuable in obtaining the degree of spoilage of the fish flesh at any particular stage (provided the activity of the specific enzyme has not been interfered with as, for example, by the use of preservative substances such as nitrites). Unfortunately they ordinarily do not allow to predict the keeping quality of the fish in the early stages of spoilage or in the case of fillets, of unknown previous history.

It has been shown that the enzyme activity is greatly influenced by the pH, the optimum being above 8.0 for enzymes of most fish spoilage bacteria. There is markedly less activity when the pH is below 7.0. This may in part explain why, for the Atlantic coast ground fish, in which the pH rises rapidly to 7.0 and higher, the trimethylamine test has been found much more satisfactory than for many Pacific coast fish which have a lower initial pH *(17)*.

Recent work on volatile acid determinations appears to promise a test with more nearly universal application *(11)*.

### Marine Bacteria Are Psychrophylic

Many bacteria which are very active in reducing trimethylamine oxide and in causing proteolysis at "room temperature," are completely inhibited at ice temperature. On the other hand, most marine bacteria isolated from the cool waters in the Northern hemisphere have been found to be able to grow, although more slowly, at ice temperatures and even down to 10° F. (—10° C.). This, of course, complicates the problem of preserving fish by means of chilling. It definitely limits their total keeping time to a matter of two to three weeks under favorable circumstances. Not only will marine bacteria grow at these temperatures, but they may, in time, even produce larger total crops than at room temperature. While, at first sight, this might all sound very discouraging, another factor enters into the picture and indicates a practical way of overcoming our difficulties. This is the fact that near

the freezing range the temperature coefficient of bacterial growth is much higher than at room temperature *(7)*. In plain language, this means that the lowering of the temperature by, say, 2° F. in the freezing range is several times as effective as lowering the temperature by the same number of degrees in the room temperature range. In fact a greater reduction in the bacterial growth rate is achieved by lowering the temperature from 37° F. (2.7° C.) to 31.5° F. (—0.3° C.) than by lowering it from 77° F. (25° C.) to 37° F. (2.7° C.). Similarly, the temperature, coefficient of activity of the enzymes of marine bacteria, including triamineoxidease, is quite high near the freezing point. A lowering of the storage temperature of cod fillets from 37° F. to 32° F. doubled their keeping quality, the actual time depending upon their original quality, while in the room temperature range it would have required a lowering by 40° F. to have achieved the same result *(3)*. Each single degree by which we can lower the temperature of all the fish in storage becomes increasingly more effective and important the closer the freezing point of the fish flesh is approached.

A group of lipolytic bacteria has recently been isolated from cod held at 32° F. (0° C.), constituting some 86 percent of 467 cultures. Although ground fish contain only about 0.5 percent fat, the fact that bacterial lipases are little affected by low temperatures may account for some of the flavor changes in chilled and frozen fish *(4)*.

### Principles of Controlling Fish Spoilage Bacteria

Control of any undesirable bacteria can be attempted by at least four means: first, by preventing, insofar as possible, bacteria from gaining access to the fish flesh, which is mainly a problem of handling and preparing the fish under sanitary conditions; second, by preventing those bacteria which have contaminated the fish flesh in spite of all precautions from reproducing themselves; third, by inhibiting insofar as possible the activity of enzymes which really cause the fish spoilage; and fourth, by keeping the interval between catching the fish and its consumption as short as possible. It is agreed, of course, that the ideal control would be to kill the bacteria at an early stage, but no practical method has been reported as yet which will accomplish this without altering the fresh fish flesh in some way.

### Spoilage Control

Regarding the first factor, that of *contamination* of the fish flesh, it has already been mentioned that the fish flesh is sterile to begin with and that the bacteria enter it, from the surface slime, through the skin or, from the intestinal contents through the linings of the belly cavity.

The impounding of live fish of the sardine and herring types to allow their intestinal contents to be eliminated and thus cease to be a source of bacteria for contaminating the fish flesh is a well known method of spoilage control exercised, particularly by canners, in various parts of the world.

The contamination of the flesh may be speeded up by any kind of rough handling of the fish, by the cutting of the skin, by the gutting operation and by heading of the fish, which helps to spread the intestinal contents over the cut surfaces of the flesh, unless the gutting is followed immediately by thorough washing. The reference to heading applies to the British wartime practice of heading trawler-caught fish at sea, which also delays the handling of the fish on deck. However, heading may assist in proper bleeding of the fish and is required for this reason in Norwegian shore-caught fish.

The initial bacterial load varies with the season, being highest in the North Sea, for example, in August. Trawler-caught fish have a higher load than line-caught fish, partly on account of the dragging of the trawl along the bacteria-rich bottom mud, and partly because of the squeezing out of the intestinal contents by the pressure in the trawl. Prolonged holding of fish on deck will also increase their bacterial load. This is particularly true in warmer weather. The original bacterial load of the fish is also increased by its contact with dirty surfaces on the deck and in the hold of the fishing vessel. Gradual replacement in modern trawlers of wooden boards and partitions on decks and in holds by non-corrosive metal is showing the way to reducing contamination of the fish from these sources.

Apart from the effects on the growth rate and activity of bacteria, low temperatures also retard penetration of the fish skin by bacteria. While after four days of holding at 45° F. (7° C.) many hundreds of millions of bacteria could be counted per square centimeter of the inner dermis and outer muscle layers, at 32° F. (0° C.) no significant penetration of the skin occurred in the same period.

It follows that fish should be thoroughly hosed on deck before gutting and thoroughly washed afterwards to remove as much of the contamination as possible.

Contamination during the filleting operation has received considerable attention in recent years. It has been shown that the keeping quality of the fillets depends largely upon the bacterial load they receive at the time of filleting rather than upon the length of previous storage. Since the greatest part of the contaminating bacteria are discarded with the skin and the skeleton, the total keeping time of iced fish can be increased by filleting. On the other hand, the fish slime contaminates filleting boards, knives and filleter's gloves so rapidly that they in turn recontaminate the fillets. With increasing age of unwashed fish, increasing contamination of the fillets occurs. By thorough mechanical washing of the fish before filleting the bacterial load on the fillets may be reduced by some 98 percent. It is obvious that the larger the contamination of the fillets, the faster they will spoil. For instance, 100 to 1,000 bacteria per cm.$^2$ will cause spoilage in 9 days; 10,000,000 per cm.$^2$ in 4 days *(2)*.

Well organized systems of fish plant sanitation, involving cleansing and chlorination *(10)*, have proved that reducing the chances of contamination of the fish to a minimum at all stages of handling, from the sea to the consumer, increases quality of the products.

Since under commercial conditions some contamination will always occur, the second means of controlling spoilage, that of *inhibiting bacterial growth*, becomes most important.

Commercially the chilling of the fish is the most practical and effective means of controlling bacterial growth as well as spoilage action. Where the industry has lagged behind is in the realization of the importance of lowering the fish temperature right down to 32° F. to 30° F. (0° C. to —1° C.) as quickly as possible and maintaining it there. The chilling of sardines and sprats in cold, weak brine or sea water is a commendable exception *(12)*. Temperatures of over 40° F. (5° C.) of fish in some parts of vessel holds are not uncommon, and in view

of our earlier statements, are largely responsible for some of the poor quality of fish landed. If this coincides with long fishing voyages, extending not only to a number of days but weeks, the limit of the keeping quality of the catch is stretched beyond the breaking point and at time of landing the earlier part of the catch is only fit for the fish meal plant. Low hold temperature storage is faced by two problems, first by an engineering one involving vessel design, hold insulation, refrigeration, etc. and second, by a human one, involving the proper training and supervision of the crew primarily responsible for the handling and stowing of the catch aboard. It has been observed on many occasions that two vessels of the same type and under the same fishing conditions may bring in catches of consistently different quality, due primarily to more responsible and intelligent stowing procedure in one case than in the other.

Tests have shown that in order to cool all the fish in the holds rapidly to 32° F. (0° C.), it is not sufficient to pile large quantities of ice on deep layers of fish. Fish in the centers of such holds may never reach 32° F. or even 36° F. (2° C.) during the return trip. Even the center of 15-inch (38 cm.) layers of fish will take 3 days to cool to 32° F. *(14)*. Only when the ice is near the fish, as in stowing alternate layers of ice and shallow layers of fish, will the temperature of the latter be lowered to 32° F. rapidly enough to be effective in retarding spoilage. It is known that the ice will melt most rapidly at the outside walls of the hold, i.e. at the skin of the vessel, under the deckhead and on the inside walls of the pens. Commercial tests have shown that auxiliary mechanical refrigeration assists greatly in preserving the ice in these locations and in maintaining uniformly low hold temperatures, particularly when this is combined with proper hold insulation augmented by jacketing. In comparative trials such boats have consistently brought in catches of higher quality than have boats with or without hold insulation and without mechanical refrigeration. In some European fishing vessels the fish, especially small fish, flat fish and the early catch of the trip, are boxed and iced aboard, thus allowing a catch of superior quality to be landed.

All that has been said concerning the effects of low temperatures on bacterial growth applies equally to the *activity of bacterial enzymes*, although some enzymes are affected less than others, e.g. the reduction of nitrite and proteolysis by certain organisms are less retarded at 31° F. (—0.6° C.) than is the reduction of nitrates and trimethylamine oxide. Also, some bacterial enzymes are active below the growth range of the bacteria.

It has been shown that concentrations of nitrites greater than 50 p.p.m. interfere with the activity of the triamineoxidease. However, the presence of small concentrations of nitrites does not necessarily interfere with bacterial growth, except at low pH. Most bacteria capable of reducing trimethylamine oxide will also reduce the nitrite. Nitrite dips have proved an effective treatment for inhibiting trimethylamine oxide reduction in fillets of such fish as cod and haddock, thereby increasing the keeping quality of the fillets. However, the effect is limited to a pH range below 7.1, i.e. to fillets of really fresh fish. Nitrite dips are of little value for heavily contaminated fish; their use should be restricted to the early stages of handling the fish.

The European system of de-icing and boxing the whole catch to display it on the fish docks for inspection and auction has one great disadvantage. The fish are held thus uniced for several hours, which, especially in warm weather, is particularly harmful to the earlier portions of the catch which may have just reached that stage in the course of spoilage when the rate of spoilage has accelerated after the initial lag.

Another delay in cooling of fish, particularly fillets, occurs when they are shipped in wooden boxes which are merely surrounded by crushed ice, the fish not having been precooled. Tests have shown that it took 48 hours to cool fish in the center of 20 lb. boxes, held in a room of 25° F. (—4° C.) (equal to refrigerator car conditions), from 50° F. (10° C.) to 32° F. (0° C.) *(13)*.

From this it can be seen that the pitfalls are many in the long chain of events from catching the fish to putting it on the consumer's table, particularly when the time element is unfavorable, either on account of long fishing voyages or long distances of distribution from the fishing ports to inland centers. In some instances the limits within which fish can be marketed as really fresh fish have already been reached, in spite of all methods of control indicated so far. The solution of this problem, as seen in many parts of the world, lies in the quick freezing ashore, or in case of long voyages, possibly in quick freezing aboard.

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# Drying by Infra-Red Radiation[a]

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**Disappointing results are avoided by fundamental knowledge of the absorption curve of the material to be dried by infra-red radiation. Usually efficiency must be sacrificed to avoid surface overheating. However, other advantages compensate for loss of efficiency.**

Infra-red radiation has aroused new interest in recent years. The development of concentrated, controlled and safe sources of infra-red in the form of electrically heated enclosed filaments has spurred its introduction into several fields, particularly in industrial drying.

Many food technologists have tried infra-red radiation for drying their pet product. There have been an almost equal number of disappointments. We say an almost equal number because in spite of all that is claimed for infra-red drying, all that has been written about it, and all the work that has been done with it, the resulting commercial applications to food processing have been few indeed. These few applications include concentrating and drying products of the sugar industry *(1)*, grated codfish, potatoes, toasted wheat germ, bread crumbs *(2)*, and a variety of fruits and vegetables *(3, 5)*.

We believe that the large number of disappointments is due to a lack of information on the fundamental properties of infra-red radiation. If this information were available and if it were taken into consideration by the food technologist before starting his project, he would be saved disappointmnet.

Infra-red has its place in drying technology, but it is not the panacea for all drying problems. It appeals because it penetrates and produces heat inside the material being dried, but its penetrating powers are limited. Sometimes its limited penetrating power is advantageous, but at the same time limited penetrating power means high surface heating and usually this is to be avoided if possible.

It is our objective here to describe some of the fundamental properties of infra-red and to present three preliminary steps which one should take before applying infra-red to any drying problem.

The following three factors are essential in understanding how infra-red heating functions:

The first is a fundamental law of light absorption. Each hypothetical layer of a given material absorbs the same percentage of infra-red energy impinging on it. Of course, the percentage varies with the material. Naturally, it is impossible to have uniform absorption of energy throughout a given thickness of material. Since the amount of energy reaching successive layers of material is constantly being reduced by absorption in the previous layers, the amount of absorptoin must necessarily decrease as the depth into the absorbing material increases. The nature of this variation with depth into the material is shown in Figure 1 where the absorption at successive depths is plotted for three different sources of infra-red energy.

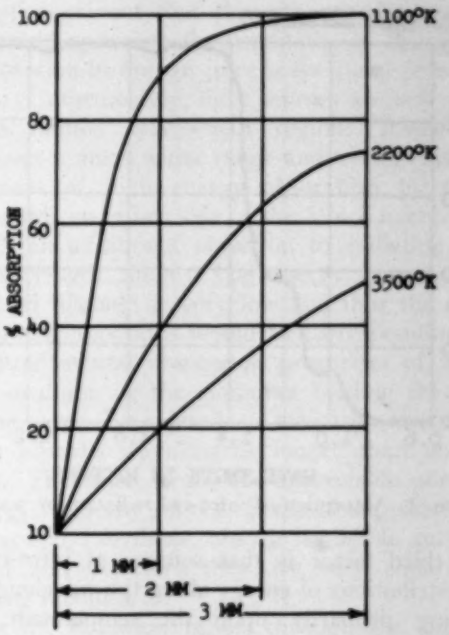


FIG. 1. The fundamental law of light absorption.

It is seen that for the 1100° K [b] source, absorption in the material is high and a large portion of the energy is absorbed very near the surface of the material,—in fact, approximately 50 percent of the energy is absorbed in the first 0.5 mm. depth. Such a condition leads to high efficiency of heating since over 99 percent of the energy is absorbed in the 3 mm. depth, but it also results in surface heating.

This illustration also shows that heating is far from uniform at all depths.

On the other hand, the energy from the 3500°K source is not so strongly absorbed and therefore penetrates more deeply into the material. This approaches uniform heating throughout the thickness but at the same time efficiency is lost because of the high transmission through the 3 mm. depth.

The 2200°K source might represent the best choice for heating this material. It represents a compromise between the high efficiency of the 1100° K source and the low surface heating of the 3500°K source.

The second important fact about infra-red heating is that the percentage of absorbed energy varies with the wavelength of the energy. The manner in which absorption of infra-red varies with the wavelength is

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[b] °K equals °C + 273. K stands for Kelvin. It is an absolute temperature scale.

illustrated in Figure 2, representing the approximate absorption curve for a 3 mm. thickness of water. Wavelengths longer than 1.4 microns are completely absorbed. Between this wavelength and the visible region starting at approximately 0.7 microns, the absorption is variable.

In order to control the depth of penetration of the energy into the material, one must know the absorption characteristics of the material and choose, if possible, a wavelength which has the desirable absorption characteristics.

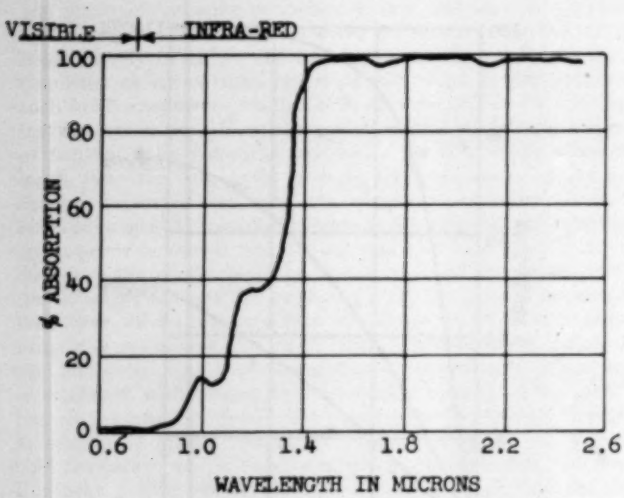


FIG. 2. Absorption of infra-red radiation by water.

The third factor is that sources of infra-red have wide distributions of energy along the wavelength scale, depending primarily upon the temperature of the source.

Unfortunately, it is impossible to choose a source having a single wavelength. Heated bodies, which are the sources of infra-red energy, give off wavelengths over a wide range. Typical distribution curves are shown in Figure 3. True, there is a wavelength of

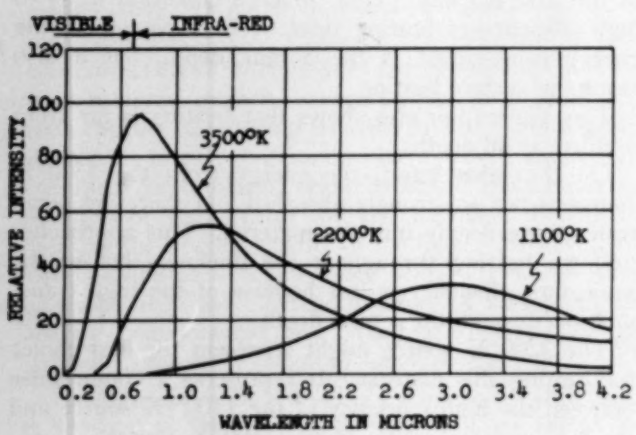


FIG. 3. Relative intensities of various sources of infra-red radiation.

maximum energy for each source and this wavelength maximum varies with the temperature of the source. However, this maximum represents only a small portion of the total energy and to utilize infra-red economically, it is necessary to use a broad band of wavelengths.

The curves in Figure 3 are drawn so that the total heat energy is the same for each curve. Actually, the total energy output of a heated filament decreases rapidly as its temperature is lowered. This becomes an important factor in some applications. For example, in using very low temperatures, a very large heating surface is necessary and it may not be practical to use enough heating surface to obtain the desired amount of heat transfer.

The above mentioned three properties of infra-red radiation are essential to an understanding of how it functions. Now let us consider the three steps which should be followed in applying infra-red to a drying problem.

The first step is determination of the absorption characteristics of the material to be dried. Let us assume that we are going to dry the material represented by the curve in Figure 2. This curve represents the approximate absorption in a 3 mm. thickness of water. We will assume that this curve has been obtained on an infra-red spectrophotometer.

The second step is to choose a light source. Suppose we choose the 2200°K light source shown in Figure 3.

The third step is to apply the fundamental law of light absorption. For this purpose the radiation source curve is shown on the same chart as the absorption curve for water in Figure 4. At wavelengths above 1.4

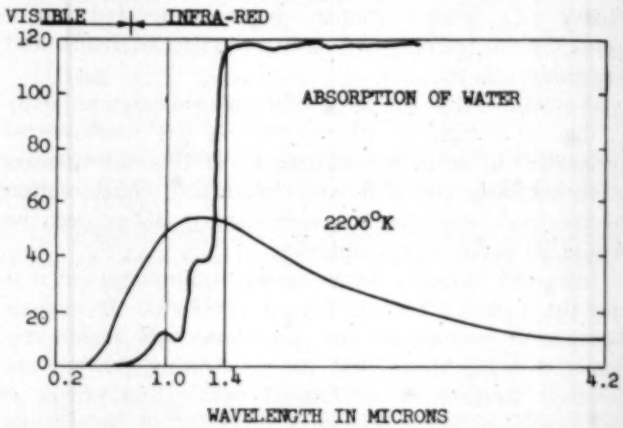


FIG. 4. Application of fundamental law of light absorption.

microns, radiation is almost completely absorbed by the water. The portion of total energy from the light source, represented by wavelengths above 1.4 microns, is approximately 65 percent of the total energy of the lamp. This is measured by the area under this portion of the curve. Thus, at least 65 percent of the total energy is completely absorbed in passing through the water.

Between wavelengths 1 and 1.4, the absorption of water is variable, perhaps on the average it is in the neighborhood of 40 percent. Also, the area under the radiation curve between these wavelengths is about 20 percent of the total energy. Thus, approximately 40 percent of 20 or 8 percent of the total energy is absorbed and 12 percent is passed through the water film.

For the wavelengths shorter than 1 micron, the absorption of water is very low and this range represents approximately 15 percent of the total energy as measured by the area under the radiation curve. Thus,

TABLE 1

*Transmission and Absorption of Infra-Red Radiation from a 2200°K Source in 3 mm. Thickness of Water*

| Wavelength Region | Percent of Total Energy Transmitted | Percent of Total Energy Absorbed |
|---|---|---|
| Above 1.4 microns | --- | 65 |
| Between 1 and 1.4 microns | 12 | 8 |
| Below 1 micron | 15 | --- |
| Total | 27 | 73 |

we have in this region none of the radiation absorbed and about 15 percent of the total energy transmitted.

The above results are tabulated in Table 1. By adding up the two columns, it is seen that approximately 73 percent of the total energy is absorbed and 27 percent is transmitted by a 3 mm. thickness of water. Referring back to Figure 1, it is seen that these figures correspond very closely to the curve for the 2200°K source. Thus the distribution of absorption in the various layers of water will be as represented by this curve in Figure 1.

The choice of the 2200°K source is obviously a compromise between excessive absorption in the surface layer on the one hand and high transmission of energy through the sample on the other. Naturally, if a light source similar to 3500°K in Figure 3 had been chosen, the figures for percent transmission through the water would have been higher and we might have ended up with a condition represented more by the 3500°K curve in Fgure 1. If we had chosen a light source represented by 1100° K in Figure 3, a much greater portion of the total energy would have been absorbed by the water film, and the conditions would be more nearly represented by the 1100°K curve in Figure 1.

The above discussion neglects entirely the absorption of radiation in the dry product. This too is important and should be taken into consideration. In many food products it is highly desirable to avoid heating the dry product as much as possible. To determine the extent of heating in the dry product one should follow the same procedure as outlined above; that is, obtain the absorption curve for the dry product and determine the extent to which the particular energy source will be absorbed in this material.

The above technique of avoiding disappointments in the application of infra-red drying may be further illustrated by actual example from our own laboratories. We were interested in drying orange juice. For this purpose we were using an approximately 1100°K source in the belief that radiation from this source was selectively absorbed in the water and not appreciably absorbed in the dry product. In this way we thought we were obtaining a dried orange juice powder which was not being overheated. It is well known that orange juice is particularly susceptible to flavor changes when it is heated. It was our objective to avoid these flavor changes.

The absorption curves for the orange juice and the dry orange juice powder are shown in Figure 5. It is seen that the orange juice has a minimum in absorption in the range between 3 and 4 microns, whereas the dry orange juice solids have a maximum in absorption in this same region.

The radiation curve for the light source is also shown in Figure 5 for comparison with the absorption curves of the other materials. It is seen that this radiation source has a maximum in the region of 4 microns.

We have applied so far steps 1 and 2 in the above mentioned procedure. Step 3 is to apply the fundamental laws of light absorption. When we do this it is perfectly obvious that this particular light source is not going to be selectively absorbed in the orange juice, instead this is the region of maximum absorption by the dry orange solids. The reasons why the process was not satisfactory become apparent immediately.

It is also evident that the only wavelength region which would approach the conditions of desired selective absorption in orange juice is the range from 5 to 7 microns. Unfortunately, light sources are not available for this limited wavelength region. Instead, they extend over a much wider range and would extend into the regions of high energy absorption by the dry orange solids on either side of the 5 to 7 micron range. There is an additional objection to radiation in this long wavelength range: The energy output from a given sized filament is very low and thus the capacity of the drying apparatus would be correspondingly low.

The fundamental absorption properties of the supporting medium, or the container holding the sample, must be also considered. Ordinary Pyrex glass strongly absorbs wavelengths longer than about 2.8 microns. Therefore, it absorbs appreciable portions of the energy from any source. Some of the plastics, such as Nylon and Polythene, absorb negligible amounts of infra-red and therefore they are very suitable as a supporting medium.

When the radiation passes through the supporting medium to reach the sample, all advantages of the penetrating power of infra-red are lost if strong absorption takes place in the supporting medium. It becomes hot, and heat is transferred to the sample by conduction.

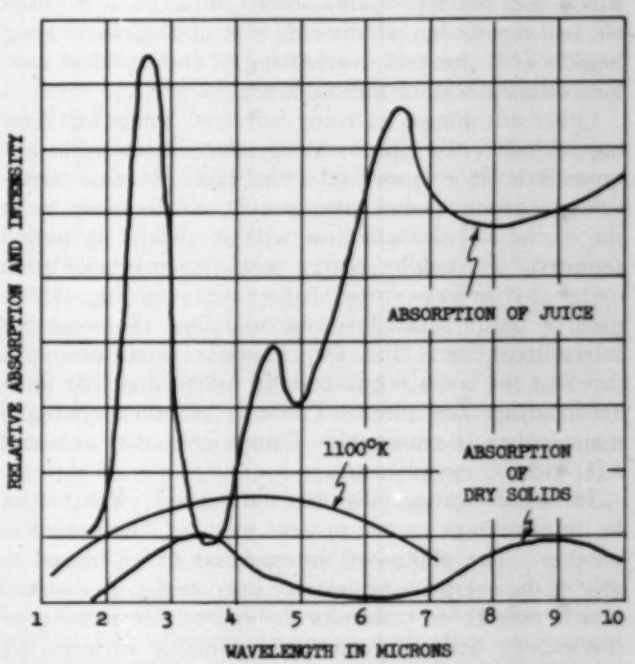


FIG. 5. Drying of orange juice by infra-red radiation.

When the radiation passes first through the sample and then through the supporting medium, the radiation not absorbed by the sample may be absorbed in the support and heat it. It is always desirable to avoid absorption in the supporting medium.

Another thing we found wrong with the above mentioned process of drying orange juice was absorption in the supporting medium. The juice was supported on a Pyrex tray and infra-red was applied from below through the tray. When the absorption characteristics of the glass were determined, it was seen immediately that about 80 percent of the radiation from the 1100°K source was absorbed in the glass. So it would seem that infra-red is not an ideal type of heating for producing heat within the material. Instead various degrees of surface heating take place depending upon the absorption characteristics of the material being heated and the temperature of the source from which the infra-red energy comes.

There can be only limited control over the factors which affect the degree of surface heating, such as the variation of absorption with wavelengths and the distribution of wavelengths in the source of energy. In spite of these limitations, the method was found useful in processes where temperature control is important.

There are clear advantages to the use of infra-red within the limits of its capabilities. The chief advantage of radiant heating is the elimination of resistance to heat transfer at gas to solid interfaces, such as exist in convection type heating, and at metal to liquid interfaces, such as exist in conduction type heating. This results in a saving in time of processing and better control of surface temperature, particularly for granular materials which are so often encountered in food processing.

A particular advantage of infra-red for evaporating heat sensitive liquids has been pointed out by Reavell *(4)*. Using as a container for the liquid a material which does not appreciably absorb infra-red, it is possible to keep its temperature at that of the evaporating liquid. This prevents overheating of the liquid in contact with the wall of the container.

Other advantages of using infra-red lamps for heating include: (1) Space saving, since lamp banks require little floor space; (2) Flexibility, because variations in grouping and arrangement can be made to fit the work; (3) Instant heat with no warm up period required, no standby power costs, no overheating of material if process stops. Automatic switching can be used to permit heated section to follow the work for intermittent feed; and (4) Pleasant conditions,—the fact that the air is not materially heated and that units are compact and clean. The cost of investment and maintenance is reasonable. Lamps are rated at about 5,000-10,000 useful hours.

Infra-red heating also has limitations. What may be an advantage in one process may be a limitation in another. The ability of the material to be heated to absorb the energy is of primary importance. A material which reflects or transmits an appreciable amount of the energy will not heat well. Metallic surfaces are good reflectors. White and red colored materials will reflect a considerable though not a major portion of the energy. On the other hand, if the material is too good an absorber, then the energy will be absorbed in the surface layer and the interior must be heated by conduction.

In relation to the control of surface overheating, infra-red lies in between dielectric heating where there is no surface overheating, and conventional types of conduction heating where the surface must be overheated.

Although low cost had previously been mentioned as an adantage, each application is different and the costs must be compared directly with other methods. In general, experience has shown that the capital investment, maintenance, and replacement costs are low. Operating efficiencies average about 90 percent, which means that this much of the power drawn from the lines is converted into useful radiant energy. Overall efficiency will depend upon the degree of absorption of this radiant energy in the material being heated, but practical applications indicate values of about 65 percent.

Radiant heating with infra-red lamps should be considered whenever a new process is being designed or an old one modernized. A properly designed system has in many cases (including several in the food field) proved to be cheaper than the older system. In addition, because of better temperature control, infra-red heating resulted in a superior product.

## Summary

The use of infra-red for drying often leads to disappointing results. This is due to popular misconceptions. It is avoided by preliminary determination of certain fundamental information. The authors present three steps for doing this:

1. Determine absorption curve for material to be dried.
2. Choose heat source.
3. Apply fundamental law of light absorption.

In applying these steps to evaporating water, one finds a limited choice of heat sources. Final choice represents a compromise between low efficiency and high surface heating. To avoid overheating, the absorption curve for a dried product is just as important as for the starting material.

Advantages of infra-red are:

1. Some control over surface overheating.
2. Low space requirement.
3. Flexibility in spotial arrangement of heaters.
4. Instant heat on and off.
5. Pleasant working conditions.

The cost of infra-red drying varies widely. It must be calculated for each application.

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# Acidification and Calcium-Firming of Canned Pimientos[a]

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**Immersion of blanched pimientos in weak citric or acetic acid or deposition of a definite quantity of acid directly in the can were simple means of lowering the pH of the canned product from pH 4.95 to 4.5 so as to permit present processes at 212° F. to be used with less danger of spoilage. Direct deposition of the acid in the can resulted in greater uniformity in pH than acidification by immersion. Citric acid tablets would appear to be easier to use than deposition of a liquid acidulant. Acidification did not affect the color. Although the added acid modified the flavor, only acidification below pH 4.3 resulted in too drastic a change in flavor. Acidification increased the drained weight of the product significantly. The use of both an acidulant and calcium chloride resulted in a highly significant increase in drained weight and in firmness of the canned product.**

## Introduction

Because of spoilage in 1947, the Georgia pimiento canning industry sponsored research in 1948 to ascertain how such spoilage could be stopped. Pimientos are processed commercially at 212° F. (100° C.). Although longer water bath cooks or pressure cooks would undoubtedly prevent spoilage, both are objectionable because they soften the product excessively. Since severe cooks are undesirable, acidification was used as an alternate procedure to bring the heat resistance of the organisms within the lethal range of present water bath cooks. Acidification appeared to be desirable not only to prevent spoilage, but, as the study progressed, as a means of eliminating danger of food poisoning. The first phase of the study, previously reported *(20)*, showed that pimientos are less acid than has been generally thought and have an average pH of 4.95.

## Review of Literature

Sane et al. *(20)* found that the pH of canned pimientos ranged from 4.6 to 5.2. Values as high as pH 5.5, though rare, have been encountered *(20)*. Culpepper et al. *(4)* were among the first to observe that the pH of red pepper may exceed 5.0. These workers stated that peppers, whether red or green, should be processed only under pressure.

Although pimientos are water-bathed and are generally close to pH 5.0, no outbreaks of botulism due to commercially canned pimientos are apparently known. There is evidence, nevertheless, that red pimientos can support the growth of *Clostridium botulinum*. Schoenholz et al. *(21)* inoculated canned pimientos with detoxified spores of *Clostridium botulinum*. Weak toxin production was demonstrated. However, these cans were not heated after inoculation. The reviews of Esselen *(6)* and Wylder *(25)* list outbreaks of botulism resulting from ingesting home-canned peppers. Most of the outbreaks involved green peppers. Green peppers are much higher in pH than red peppers *(20)*. To determine whether danger exists when red pimientos are water-bathed, the National Canners Association has set up comprehensive studies to establish the pH levels at which pimientos will support growth and permit toxin production *(23)*.

Pimientos support the growth of at least three spore-forming anaerobes characterized by a gassy, butryic, cheesy smelling fermentation *(18)*. The chief trouble-maker is possibly an organism of the *Clostridium pasteuranium* type.

One reason why spoilage occurs is that heat penetration in the cans is slow *(23, 24)* due to tight packing and layering of the product. Acidification has been used off and on in the industry to decrease the thermal resistance of the spoilage organisms. Fellers *(9)* recommended that the 28-ounce cans be acidified with distilled vinegar which appears to be more toxic toward many microorganisms than other common edible organic acids. Levine and Fellers *(14, 15)*, Erickson and Fabian *(5)*, Morse et al. *(16)*, and Anderson et al. *(1)* have reported upon the toxic action of acetic acid toward different microorganisms. Some of these studies *(1, 5)* suggest that acetic acid is more inhibitory toward some acid-tolerant, spore-formers than are citric or lactic acids. Both acetic and citric acids have been investigated as acidulants for pimientos by the National Canners Association *(2)* and Wessel and Roberts *(23)* investigated acidification simultaneously with this study.

Acidification is often used commercially for Brussel sprouts, onions, artichokes, and potato salad because these products become mushy when cooked under pressure *(22)*. However, mushiness in foods has not only been combatted by adjusting the pH to permit mild cooks but also by adding firming agents *(13)*. Calcium salts have become established, legal firming agents in the canning of tomatoes and in frozen apples *(3, 7, 8, 10, 11, 17)*. Powers and Sane *(19)* observed, based upon limited studies, that a combination of an acidulant to inhibit spoilage organisms and calcium chloride to retain a firm texture permitted pimientos to be water bathed without spoilage and with little softening.

## Experimental Procedure

Five experimental packs consisting of 947 four-ounce cans (211 × 200) were packed in two canneries. The pimientos were acidified: (1) by submersing them in acids of various strengths for different periods of time, then permitting them to drain for 15 seconds; (2) by depositing an accurately measured volume

[a] Some of the data are taken from a thesis submitted by Ruth H. Sane to the Graduate Faculty of the University of Georgia in partial fulfillment of the requirements for the degree, Master of Science in Agriculture.

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of acid directly into the can, or (3) by depositing tablets of anhydrous citric acid containing 100 mg. of acid in the can. Acetic, citric, phosphoric, and hydrochloric acids were tried in the first pack. Hydrochloric acid was used without intention of practical application. Some packs also included cider vinegar. At present both citric acid and vinegar are allowed as acidulants for pimientos *(2)*.

Combination treatments consisting of both an acidulant and calcium chloride were packed in two ways: (1) various combinations of the acidulant and calcium chloride were prepared and the pimientos were dipped as described above, and (2) the acidulant-calcium chloride mixture was added directly to the can. The maximum amount of calcium chloride in any of the dipping solutions was 1 percent and that added directly to the cans was 0.07 percent, based upon a 4-ounce fill. Actually the 211 × 200 can holds 118.3 grams of water at 68° F. (20° C.).

Immediately following processing and at intervals thereafter, the pH, total acidity, buffering capacity, and drained weight of the contents were determined. The procedures followed are described in a previous publication *(20)*. The organoleptic qualities of selected lots were evaluated by a standardized taste-panel and the firmness was measured by determining the force required to drive a disk of 1.9 cm. diameter through the pod.

## Experimental Results

Immersion of pimientos in 1 percent citric acid for 1.5 minutes or in 2 percent acid for one minute, followed by 15 seconds draining, lowered the pH of the canned product to pH 4.5. If pH 4.7 is accepted as the desired degree of acidification *(2)*, then a 1.5 minute dip in 0.5 percent citric acid or a 30 second dip in 1.0 percent acid would suffice. When 5 percent vinegar was used as the acidulant, a one minute dip was necessary to lower the pH to 4.5. Immersion in 1 percent phosphoric acid for one minute also lowered the pH to 4.5. The effects of other acids, concentrations, and dipping times may be seen in Table 1.

Because citric acid and acetic acid (vinegar) are permitted as acidulants by the Food and Drug Administration, the choice of acidulants naturally narrows down to these. As will be pointed out later, citric acid is more desirable than acetic acid because it modifies the flavor less; however, acetic acid may permit shorter cooking times to be used at equal pH levels because of its greater germicidal action *(1, 5)*.

Although immersion is a satisfactory mode of acidifying, it has certain disadvantages, among which are: (1) maintenance of the desired acid concentration in the bath, (2) lack of uniformity due to pods occasionally acting as cups during draining with the result that excessively unequal amounts of acid are carried into the cans, and (3) wastefulness.

Direct addition of the acidulant to the cans resulted in more uniform pH levels than immersion. Both liquid and solid acidulants were equally effective. Because tablets can be deposited with conventional machines, the use of pelleted citric acid would appear to be particularly desirable in terms of automatic operation with minimum care and readjustment of existing packing lines.

The direct addition series showed that early in the season from 200 to 250 mg. of citric acid monohydrate added to 4-ounce cans will reduce the pH to approximately 4.5. Late in the season from 150-180 mg. were required. In general, as the season progressed, less citric acid was required to lower the pH to 4.5. When acetic acid was used, 500 mg. per 4-ounce can was required early in the season. When 0.07 percent $CaCl_2$ was added in conjunction with the citric acid, from 115 to 145 mg. of citric acid adjusted the pH to approximately 4.5. The effect of different amounts of citric acid alone and in combination with $CaCl_2$ may be seen in Table 2.

TABLE 1

*Comparison of Various Acidulants, Acid Strength, and Immersion Period Upon the pH of Pimientos in 4-ounce Cans*

| Acid | Acid strength, percent | Calcium chloride present, percent | Immersion period in seconds | pH | Acidity (as citric), percent | Time in season |
|---|---|---|---|---|---|---|
| Citric | 0.5 | ..... | 60 | 4.82 | 0.227 | Early |
| " | 0.5 | ..... | 90 | 4.65 | 0.264 | " |
| " | 1.0 | ..... | 30 | 4.66 | 0.295 | " |
| " | 1.0 | ..... | 60 | 4.63 | 0.332 | " |
| " | 1.0 | ..... | 90 | 4.49 | 0.272 | Middle |
| " | 1.0 | 0.05 | 90 | 4.39 | 0.337 | " |
| " | 1.0 | 0.10 | 90 | 4.35 | 0.227 | " |
| " | 1.0 | 0.10 | 90 | 4.08 | 0.285 | Late |
| " | 1.0 | ..... | 120 | 4.55 | 0.285 | Middle |
| " | 1.0 | 0.10 | 120 | 4.38 | 0.351 | " |
| " | 2.0 | ..... | 60 | 4.46 | 0.373 | " |
| " | 2.0 | ..... | 90 | 4.35 | 0.390 | " |
| Acetic | 0.2 | ..... | 60 | 4.95 | 0.195 | Early |
| " | 0.2 | ..... | 90 | 4.98 | 0.239 | " |
| " | 0.5 | ..... | 30 | 4.85 | 0.240 | " |
| " | 0.5 | ..... | 60 | 4.89 | 0.286 | " |
| " | 10.0 | ..... | 60 | 4.16 | 1.33 | Middle |
| " | 10.0 | ..... | 90 | 4.12 | 1.40 | " |
| " | 10.0 | ..... | 120 | 4.36 | 1.40 | " |
| " (vinegar) | 2.0 | ..... | 60 | 4.96 | 0.194 | Early |
| " (vinegar) | 2.0 | ..... | 90 | 4.9 | 0.132 | " |
| " (vinegar) | 5.0 | ..... | 30 | 4.96 | 0.179 | " |
| Phosphoric | 0.1 | ..... | 30 | 4.95 | 0.207 | " |
| " | 0.1 | ..... | 60 | 4.92 | 0.210 | " |
| " | 0.5 | ..... | 60 | 4.95 | 0.189 | " |
| " | 0.5 | ..... | 90 | 4.96 | 0.172 | " |
| " | 1.0 | ..... | 60 | 4.47 | 0.377 | Middle |
| " | 1.0 | ..... | 90 | 4.35 | 0.401 | " |
| " | 1.0 | ..... | 120 | 4.31 | 0.406 | " |
| Hydrochloric | 0.01 | ..... | 30 | 5.09 | 0.189 | Early |
| " | 0.01 | ..... | 60 | 5.08 | 0.159 | " |
| " | 0.005 | ..... | 60 | 5.10 | 0.193 | " |
| " | 0.005 | ..... | 90 | 5.05 | 0.154 | " |
| Control | ..... | ..... | .... | 5.10 | ..... | " |
| " | ..... | ..... | .... | 4.90 | ..... | Late |

Examination of Table 2 shows that to attain any desired pH level, less citric acid was generally required when in combination with $CaCl_2$ than when the acid was used alone. Because of such variables as seasonal changes in the pimientos themselves and normal packing and sampling errors, there was considerable variation in pH at each level of acid added within each of the two treatments; nevertheless there was a definite tendency for the acid-$CaCl_2$ samples to exhibit lower pH values than the acid-treated samples when the same amount of acid was deposited in the cans. A series of packs put up in 1949 using different calcium salts in combination with citric acid also showed the same trend: combination of $CaCl_2$ with citric acid resulted in lower pH values than the use of the same amount of citric acid alone.

## Color and Flavor

The various treatments did not affect the color of the canned product as judged by visual examination. The red pigment was also extracted in carbon bisulfite and its transmission measured at 10 mμ intervals in a Beckman Model DU spectrophotometer in the range of 220 to 1000 mμ. No appreciable differences existed in the absorption curves of the various samples.

TABLE 2

*Effect of Amount of Acidulant Used Alone or With Calcium Chloride Deposited Directly to the Can Upon the pH of Pimientos*

| Acid | Mg. acid per 4-oz. can | Calcium chloride added, percent | pH | Acidity (as citric), percent | Time in season |
|---|---|---|---|---|---|
| Citric | 70 | ..... | 4.79 | 0.213 | Late |
| " | 70 | .07 | 4.62 | 0.222 | " |
| " | 100 | ..... | 4.65 | 0.250 | Middle |
| " | 100 | ..... | 4.74 | 0.218 | Late |
| " | 115 | .07 | 4.49 | 0.339 | " |
| " | 140 | ..... | 4.58 | 0.260 | " |
| " | 140 | .07 | 4.30 | 0.229 | " |
| " | 145 | .07 | 4.35 | 0.272 | " |
| " | 150 | ..... | 4.43 | 0.260 | " |
| " | 170 | .07 | 4.35 | 0.264 | " |
| " | 180 | ..... | 4.49 | 0.467 | " |
| " | 180 | .07 | 4.34 | 0.256 | " |
| " | 200 | ..... | 4.58 | 0.300 | Early |
| " | 225 | .07 | 4.20 | 0.104 | Late |
| " | 240 | ..... | 4.22 | 0.335 | " |
| " | 240 | ..... | 4.27 | 0.314 | " |
| " | 240 | .07 | 4.23 | 0.294 | " |
| " | 250 | ..... | 4.43 | 0.412 | Early |
| " | 300 | ..... | 4.23 | 0.510 | Middle |
| " | 310 | ..... | 4.19 | 0.333 | Late |
| " | 310 | .07 | 4.17 | 0.350 | " |
| " | 370 | .07 | 4.17 | 0.350 | " |
| " | 500 | ..... | 4.06 | 0.480 | Early |
| Acetic | 500 | ..... | 4.36 | 0.556 | " |
| " (vinegar) | 500 | ..... | 4.45 | 0.571 | " |
| Acetic | 500 | ..... | 4.37 | 0.632 | Middle |
| Phosphoric | 150 | ..... | 4.29 | 0.449 | " |
| " | 50 | ..... | 4.69 | 0.317 | Early |
| " | 100 | ..... | 4.66 | 0.315 | " |
| Control | ..... | ..... | 5.10 | ..... | " |
| " | ..... | ..... | 4.90 | ..... | Late |

The pimientos were tasted repeatedly by a trained tasting panel of six persons. Three housewives and a home economist were included in the panel to secure the homemaker's point of view as well as that of research workers. Four samples were tested at a time with one of the samples being a duplicate. The taste tests revealed that the judges could detect differences in acidity at increments of approximately 0.1 pH unit. In general, the acidity was not considered excessive until the pH was below 4.3. On a preference basis, some of the judges actually preferred the mildly acidified pimiento (pH 4.7-4.5) on the grounds that the flavor was more sprightly. Citric acid affected the flavor less than did acetic acid. Whenever $CaCl_2$ treated cans were included, the judges could invariably detect these cans by the firmer texture of the product. There was a tendency for the $CaCl_2$-acid treated pimientos to be rated slightly less acid than the acid-treated pimientos at the same pH level. Although the $CaCl_2$-treated pimientos were slightly bitter, it should be mentioned that the level of $CaCl_2$ chosen need not be as high as 0.07 percent. A more extensive series of packs put up in 1949, not completely analyzed yet, tentatively indicates that about 0.008 percent Ca derived from $CaCl_2$, calcium citrate, or $CaHPO_4$ provides adequate firming. This equals 0.022 percent $CaCl_2$.

## Firmness

The results of firmness measurements are shown in Figure 1. Acidification did not significantly increase the firmness of pimientos over that of the control as judged by application of Student's "t" test at the 5 percent level. A highly significant increase in firmness occurred when $CaCl_2$ was used. The range and average values for each treatment are shown in Table 3.

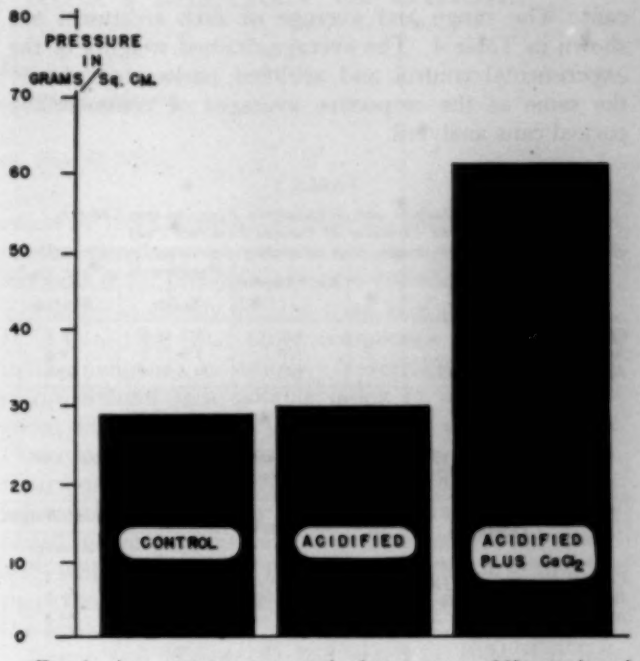


FIG. 1. Average pressure required to puncture 360 samples of canned (4-ounce) pimientos.

## Drained Weight

Although only the combination treatment of $CaCl_2$ plus citric acid increased the firmness of the pimientos significantly, acidification both alone and with $CaCl_2$ increased the drained weight of the cans significantly over that of the control (Figure 2). The increase was significant at the 5 percent level. Acidification plus $CaCl_2$ resulted in a much greater increase in the average drained weight. This increase was highly signifi-

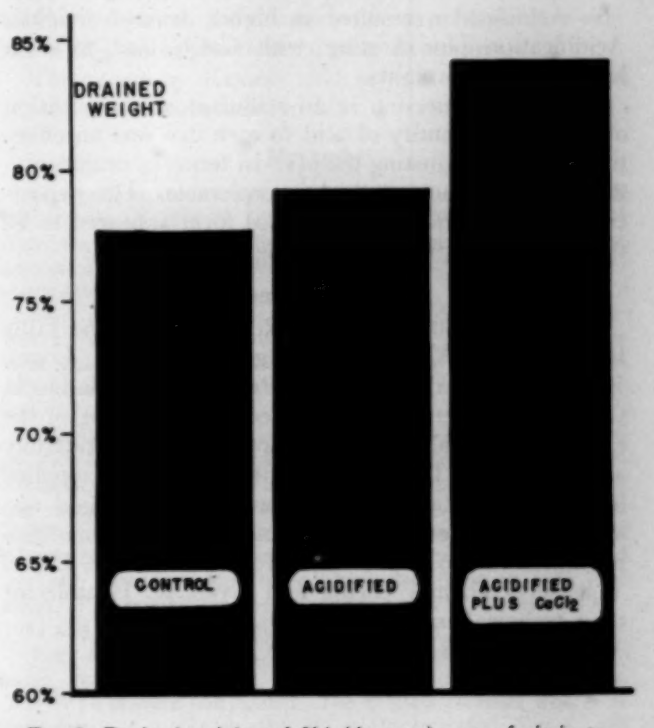


FIG. 2. Drained weights of 214 (4-ounce) cans of pimientos.

cant. The range and average of each treatment are shown in Table 4. The average drained weights of the experimental control and acidified packs were nearly the same as the respective averages of commercially packed cans analyzed.

TABLE 3

*Effect of Acidification and Acidification Plus Calcium Chloride Upon the Firmness of Canned Pimiento Pods*

| Treatment | No. Samples | Pressure in g. per cm.² | |
|---|---|---|---|
| | | Range | Average |
| Control | 120 | 9.7-56.5 | 28.7 |
| Acidification | 120 | 7.9-77.8 | 29.8 |
| Acidification plus $CaCl_2$ | 120 | 24.6-95.8 | 60.8 |

TABLE 4

*Drained Weights of Experimentally Packed Control, Acidified, and Acidified Plus Calcium Chloride-Treated Pimientos*

| Treatment | No. Samples | Percentage Drained Weight | |
|---|---|---|---|
| | | Range | Average |
| Control | 45 | 70.0-89.0 | 77.7 |
| Acidified | 104 | 70.0-86.5 | 79.2 |
| Acidified plus $CaCl_2$ | 65 | 75.0-90 | 84.1 |

## Summary

1. Mild acidification of canned pimientos to a pH level of 4.7-4.5 did not adversely affect flavor or color. Citric acid affected the flavor less than acetic acid.

2. Depending upon the time of season, from 150-250 mg. of citric acid monohydrate was required per 4-ounce can to lower the pH to 4.5. When 0.07 percent $CaCl_2$ (based on the net weight of the contents of the can) was added as a firming agent with the acidulant, the pH tended to be lower than when the same amount of acid was added without $CaCl_2$.

3. The use of $CaCl_2$ resulted in the retention of a firm texture with standard and extra long cooks.

4. Acidification resulted in higher drained weights. Acidification plus firming with $CaCl_2$ lead to even higher drained weights.

5. Either immersion in an acidulant or the addition of a definite quantity of acid to each can was an effective means of adjusting the pH. In terms of uniformity, the direct addition method is preferable. The deposition of solid citric acid in pelleted form appeared to be the simplest method of acidifying.

## Acknowledgments

The cooperation of Mr. C. Roess May, of the Hills Brothers Co., Woodbury, Georgia, and Mr. J. Logan Bloodworth, of the Cherokee Products Co., Haddock, Georgia, who permitted and aided in the packing of the experimental packs in their canneries is gratefully acknowledged. The tablets of citric acid were supplied by Chas. Pfizer and Co. A portion of the funds was supplied by the Georgia Canners Association. Appreciation is also expressed to John B. Zuccaro, Lionel W. Mills, Thomas Glenn, and Evan K. Heaton for their technical assistance.

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# Effect of Irrigation on the Yield and Pungency of Onions[a]

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**Six varieties of onions were grown and subjected to three different irrigation treatments. Even though the onions were grown part of the year when there were winter rains, the yield was increased by irrigation about 125 percent. Nonirrigated bulbs are slightly higher in dry matter or total solids but pungency is not greatly affected by the irrigation treatment.**

The production of onion bulbs, of both early and late types, is one of a series of irrigation studies that has been made at this station. Results of the work with several other truck crops have previously been reported *(4, 10-14)*. Yield of onions, a shallow-rooted crop, has been appreciably increased by irrigation. This was true even though part of the growth was made during the rainy season, which occurs in California from November to April. The study presently described also includes the effect of irrigation on percentage of dry matter and on relative pungency.

## Review of Literature

Numerous investigations have been made upon the effect of irrigation on onion yield. Fortier *(6)* in Utah made a report as early as 1893 and McClatchie *(15)* in Arizona about 1900. Other reports deal with onions grown in Missouri, Texas, Puerto Rico, Illinois *(8)*, New Jersey, Michigan *(9)*, Iowa *(5)*, and Utah *(20-22)*. The methods used in conducting these experiments were varied but usually resulted in substantially increased yield. Irrigation was of three types, surface, sub-surface, and sprinkling.

With a shallow-rooted crop like onions, several irrigations would be indicated as essential. Mortensen and Hawthorne *(16)* did not measure the water applied but learned that sixteen irrigations produced fewer onions than six irrigations in 1931-32 and eight irrigations in 1932-33. In both years the plots received some rainfall. In tests comparing several vegetables, onions were frequently the crop giving the greatest increase in yield.

Curry *(2, 3)* in New Mexico, reported extensive irrigation tests on onions in irrigated plots. He found that the larger amounts of water did not affect seed stalk development and resulted in no significant change in the moisture content of bulbs. In fact, the heavier irrigation treatments produced a larger percentage of No. 1 bulbs, which stored better than the bulbs of the other treatments.

Platenius *(17)* described a method for determining the pungency of onions, based on the assumptions that onion oil has a definite composition and that differences in the pungency of onions are due to the different amounts of oil present and to the volatile sulfur content. The latter is mostly derived from allyl propyl disulfide. It is now clear that other compounds also contribute to the pungency of onions. Nevertheless, the volatile sulfur content is a suitable index to ascertain differences in pungency. A photometric modification of Platenius' method was described by Currier *(1)*. Platenius and Knott *(18, 19)* indicated that pungency increases with maturity and that the onions should be tested just as the tops fall over. Since onions are stored and used over a period of several months, it seems that they should maintain their pungency differences over the entire period.

Erwin and Haber *(5)* had noted in 1934 that irrigated onions were milder in pungency. Platenius and Knott *(19)* also called attention to the fact that soil moisture affected pungency. They grew three varieties of onions, irrigating one end of the field with a sprinkler. An inch of water was added each week for 17 weeks. They found that irrigation increased the size of bulbs considerably but decreased the sulfur content. Onions with no irrigation showed 22.2, 3.4, and 5.8 percent higher volatile sulfur content than the onions grown without irrigation. When grown in drums with differing water table, the onions having the lowest water table showed the greatest increase in sulfur content. Even if pungency was increased by a lack of irrigation, the resulting decrease in yields would make this an impractical farming procedure.

The paper by Kramer *(7)* gives a good review of plant soil moisture relationships.

## Methods

The present studies were made at Davis, California, during the seasons of 1941-42 and 1942-43 on a sedimentary soil of Yolo loam. A preliminary trial in the spring of 1941 gave results similar to those described in this paper for the subsequent tests.

Seed of both early and late varieties, obtained from commercial sources, was planted in nurseries. The young onions were transplanted into field beds, two rows to a bed, on beds 40 inches apart. The plants were spaced 4 inches apart in the row.

The early varieties were seeded on September 10 in 1941 and on October 8 in 1942 and were transplanted to the beds on December 18, 1941 and December 29, 1942, respectively. Seeding dates for the late varieties were January 27, 1942 and October 20, 1942, with corresponding transplanting dates of March 26, 1942 and February 2, 1943. The onions harvested in 1942 were replicated three times, and those in 1943 four times. The rainfall for the two years was 21.2 inches in 1941-1942 and 17.8 inches in 1942-1943.

Four types of plots (A, B, C, and D) were each planted to three varieties of onions, 4 rows (1/270 acre) per variety. The A plots were unirrigated. The B plots received what was considered an ample amount of irrigation water. The C and D plots received successively lesser amounts of water. These

[a] Presented at the Ninth Annual Meeting of the I. F. T., San Francisco, California, July 13, 1949.

[b] Data on number of applications and inches of water applied in irrigation treatments have been supplied by L. D. Doneen of the Division of Irrigation.

onions, planted during the rainy season (November to April), were also able to use the soil moisture from rain. All plots to be irrigated received the same amount of water at each irrigation, usually less than 2 inches. Since C and D plots were irrigated less frequently than B plots, their total application of water was smaller.

The usual cultural care for onion production was given. This work was performed immediately after the start of World War II when the available labor supply was poor and unskilled. Some of the large experimental errors in 1942 can probably be attributed to this factor. When 15 to 25 percent of the onion tops had fallen over on several plots, the matured bulbs on all plots were harvested, dried, topped, and stored in onion crates. As they matured, the remaining onions on all plots were harvested at weekly intervals. The federal grades were used to determine the quality and were expressed in terms of No. 1 onions. Samples for storage trials, pungency, and drying ratio determinations were stored in the onion-bulb house, where temperatures are controlled by air ventilation. These conditions have given satisfactory storage over a period of years. The samples weighed each about 25 pounds in 1942 and nearly 40 pounds in 1943. The dry weight determinations were made at 70° C. (158° F.) in a draft oven. The drying ratios were determined by a commercial drier, as indicated in Table 4. Drying ratio refers to the pounds of raw onions required to produce a pound of dry onions. A drying ratio of 9.0 indicates that nine pounds of onions were needed to produce one pound of the dried produce; a figure of 12 indicates a smaller yield upon drying. Onion pungency was rated by the method of Platenius *(17)*.

## Results and Discussion

As shown in Table 1, irrigation gave increased yields in all comparisons. These increases were proportional to the amount of water applied to the plants. The wet (B) and dry (A) treatments in 1942 were always significant, but only about one half of the comparisons showed important differences between the medium (C) and wet (B) treatments. With one minor exception, the 1943 results showed significant differences in yield between all treatments. The comparison between the wet (B) and the medium (C) treatments of the Grano onion was not significant. Differences between the medium (C) and light (D) irrigation treatments in 1943, however, were all significant. The increased yield of the C plots was due to one extra application of water (1.7 inches). The lower yields of early onions in 1943 may be partly explained by the smaller winter rainfall. The yields in Table 1 are No. 1 onions, representing about 88 percent of all those harvested. For the sake of brevity, the data have been omitted on California Early Red and Sweet Spanish, both of which were also grown each year. The increased yields reported from irrigation have been due to death of plants as well as to decreased size of bulb on nonirrigated plots. Though equal numbers of plants were set on each plot, a larger number of onions was usually harvested from the irrigated plots.

The effect of insufficient soil moisture upon the appearance of onions is of interest in detecting extreme cases of moisture deficiency. Plant growth was at a reduced rate on plots lacking sufficient soil moisture. The plants grown on the latter plots were a darker green at first but showed some drying and dying of leaf tips at advanced stages of moisture starvation. There was no wilting, although this has been observed in the greenhouse when the plants were growing in pots of small soil volume. Insufficient soil moisture was responsible for small bulb size, as is discussed later. Irrigation treatment did not seem to affect premature seeding appreciably, although there was some bolting on the early onions in 1943. The amount, however, was less than one-half of one percent.

The data in Table 2 illustrate the effect of irrigation on the size of bulb. In all cases the size was proportional to the amount of irrigation water applied. Most of these differences were significant.

TABLE 2

*Effect of Irrigation on the Weight of No. 1 Bulbs*

| Treatment | Inches of water | Pounds per No. 1 bulb | | Inches of water | Pounds per No. 1 bulb | |
|---|---|---|---|---|---|---|
| | | Grano | Stockton Yellow Globe | | Australian Brown | Southport White Globe |
| | | 1942 | | | | |
| A. Dry | 0.0 | 0.32 | 0.32 | 0.0 | 0.11 | 0.16 |
| B. Wet | 11.2 | 0.56 | 0.64 | 18.9 | 0.21 | 0.25 |
| C. Medium | 6.6 | 0.49 | 0.55 | 10.6 | 0.17 | 0.21 |
| L. S. D. odds 19:1 | | 0.15 | 0.06 | | 0.04 | 0.04 |
| | | 1943 | | | | |
| A. Dry | 0.0 | 0.18 | 0.12 | 0.0 | 0.11 | 0.14 |
| B. Wet | 13.1 | 0.34 | 0.21 | 27.3 | 0.23 | 0.31 |
| C. Medium | 5.3 | 0.31 | 0.18 | 14.1 | 0.21 | 0.27 |
| D. Light | 3.6 | 0.26 | 0.13 | 9.0 | 0.15 | 0.17 |
| L. S. D. odds 19:1 | | 0.05 | 0.04 | | 0.06 | 0.04 |

Onions from each plot were graded according to U. S. grades. In most cases the onions from the different plots were quite similar in grade. Sometimes the nonirrigated (A) plots were higher in percentage of No. 1's, but more frequently the irrigated plots gave the higher percentage. While some of these differences were significant, the smaller size of the nonirrigated onions was a handicap in any such comparison. Irrigation seemed to have little real effect on the grade of

TABLE 1

*Effect of Irrigation on the Yield of Onions*

| Treatment | Inches of water | Number of irrigations | 50-pound sacks of No. 1's per acre | | Inches of water | Number of irrigations | 50-pound sacks of No. 1's per acre | |
|---|---|---|---|---|---|---|---|---|
| | | | Grano | Stockton Yellow Globe | | | Australian Brown | Southport White Globe |
| | | | 1942 | | | | | |
| A. Dry | 0.0 | 0 | 426 | 419 | 0.0 | 0 | 102 | 102 |
| B. Wet | 11.2 | 6 | 653 | 855 | 18.9 | 9 | 297 | 287 |
| C. Medium | 6.6 | 3 | 620 | 719 | 10.6 | 4 | 236 | 214 |
| L. S. D. odds 19:1 | | | 171 | 23 | | | 72 | 34 |
| | | | 1943 | | | | | |
| A. Dry | 0.0 | 0 | 203 | 101 | 0.0 | 0 | 71 | 130 |
| B. Wet | 13.1 | 8 | 476 | 272 | 27.3 | 11 | 335 | 453 |
| C. Medium | 5.3 | 3 | 438 | 235 | 14.1 | 4 | 248 | 369 |
| D. Light | 3.6 | 2 | 313 | 137 | 9.0 | 3 | 175 | 221 |
| L. S. D. odds 19:1 | | | 51 | 6 | | | 56 | 74 |

onions. These data have been reported in detail in a mimeographed publication by MacGillivray and Doneen *(13)*.

Bulbs matured earlier (Table 3) and were smaller in size as a result of insufficient soil moisture. Some of the variations shown in the table were due to the harvest of the three varieties at one time. The data could have been obtained more accurately if this point had been considered earlier. In all cases the non-irrigated

TABLE 3

*Percentage of Bulbs Mature at First Harvest (Figures are averages for three varieties)*

| Treatment | Early Varieties | | Late Varieties | |
|---|---|---|---|---|
| | 1942 | 1943 | 1942 | 1943 |
| | *percent* | *percent* | *percent* | *percent* |
| A. Dry | 27.8 | 28.4 | 40.9 | 19.8 |
| D. Light | ..... | 13.5 | ..... | 6.1 |
| C. Medium | 10.5 | 21.1 | 23.9 | 5.0 |
| B. Wet | 7.0 | 12.2 | 16.3 | 4.1 |

treatment gave the greatest percentage of early bulbs. In all except one case the wet treatment produced the smallest percentage of early yield. This response can probably be explained by a cessation of growth due to a lack of available water which causes the bulb to mature.

Samples of No. 1 onions were placed in common storage for about three months to determine whether irrigation affected storage life. The early varieties suffered considerably more loss than the late ones from the two primary causes, sprouting and rotting. The nonirrigated (A) onions (with the exception of Australia Browns in 1942) showed the greatest loss in weight during this period. The reason is not known for the differences in keeping qualities of those receiving the several irrigation treatments, but very likely rest period may have been a factor. Since nonirrigated onions matured earlier, it seems probable that their rest period was also over earlier, thus resulting in more sprouting. Though this factor helps to explain some of the differences found, other conditions may also have been responsible, since the weight of sprouted onions was not determined.

## Dry Matter and Pungency

Onions produced in both 1941 and 1942 were analyzed for pungency, but dry matter determinations were confined to the 1942 harvests. The 1942 data are found in Table 4. Since there is a close relationship between percentage of dry matter and drying ratio, the two will be considered together. Irrigation treatment seemed to affect the percentage of dry matter in early onions only, though the differences were not large. In five comparisons the nonirrigated treatment required the smallest weight of onion bulbs to produce a pound of dried onions. Since irrigation greatly increases yield, a grower can scarcely afford to raise nonirrigated onions unless the price per sack is higher. Because of the greater acre yields, irrigation likewise will result in the production of a greater amount of dried onions per acre.

Irrigation treatment did not greatly affect the sulfur content, as was indicated by the index of pungency obtained according to the method of Platenius *(17)*. In most cases, the onions from the nonirrigated plots

TABLE 4

*Effect of Irrigation on Dry Matter, Pungency, and Drying Ratio of Onions (1942)*

| Treatment | Early Varieties | | | Late Varieties | | |
|---|---|---|---|---|---|---|
| | Dry matter, percent | Pungency (volatile sulfur) p.p.m. | Drying ratio [b] | Dry matter, percent | Pungency (volatile sulfur) p.p.m. | Drying ratio [b] |
| | Early Grano | | | Southport White Globe | | |
| A. Dry | 7.7 | 51 | 12.7 | 10.2 | 161 | 9.2 |
| B. Wet | 6.8 | 64 | 13.3 | 11.1 | 180 | 8.1 |
| C. Medium | 6.6 | 56 | 13.3 | 11.1 | 186 | 9.2 |
| | Stockton Yellow Globe | | | Sweet Spanish | | |
| A. Dry | 8.6 | 67 | 10.6 | 7.6 | 93 | 10.4 |
| B. Wet | 8.4 | 77 | 11.0 | 7.9 | 101 | 11.0 |
| C. Medium | 8.3 | 81 | 11.7 | 8.0 | 102 | 10.9 |
| | California Early Red | | | Australian Brown | | |
| A. Dry | 10.2 | 73 | 9.7 | 13.0 | 169 | 7.6 |
| B. Wet | 9.3 | 76 | 10.5 | 13.1 | 184 | 7.9 |
| C. Medium | 9.6 | 73 | 10.4 | 12.7 | 185 | 7.9 |

[b] Pounds of cured onions required to produce one pound of dried onions. The determinations were made by the Basic Vegetable Products Co. of Vacaville, California.

possessed the least pungency. Similar data were obtained on the 1941 crop. Of the three varieties tested in 1941, only Sweet Spanish had a greater sulfur content in the nonirrigated onions. The data of Platenius and Knott *(19)*, on the other hand, indicated that low soil moisture increased the pungency of onions. In our trials irrigation increased the total amount of volatile sulphur produced per acre, but did not greatly affect the percentage composition of the onions as to pungency.

## Summary

In a semi-arid area, where the winter rainfall averages 17 inches, irrigation markedly affected the growth of onions. The yield and size of bulb was increased by irrigation. Insufficient soil moisture caused earlier maturity. Grade, storage life, dry matter, drying ratio, and pungency were not greatly influenced by irrigation. This response in onions is explained by the shallow root system of the crop.

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# Improved Methods for Evaluating Starch for Specific Uses[a]

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**Procedures for the evaluation of starches intended for specific industrial processes are outlined. These procedures are based upon the flow characteristics of slurries of ungelatinized starch, changes which take place in the viscosity and microscopic appearance of starch slurries during a heating cycle, and the susceptibility of starches to amylase action at relatively low temperatures. The interpretation of these measurements and observations, as applied to starches intended for specific uses, is discussed.**

The importance of starch in the food processing industry is recognized when it is realized that of all types of food materials processed starch in its many forms is the most widely used. Although starch enjoys this very prominent position, little is known about the accurate objective evaluation of starch in terms significant to the processing industry. Too often starch specifications in the conventional terms of chemical analysis, gelatinizing temperature, and Scott viscosity have no relationship to use characteristics. The tests and observations discussed in this paper have been found to be related to processing characteristics during use and to finished product quality when dealing with researches on corn starch puddings, tapioca puddings, quick-cooking rice, cereals and some other related food products.

In our researches we have found that the use characteristics of the starch and finished product quality are most closely related to water absorption, swelling, rupture, viscosity and finally gel formation. With the exception of the last, gel formation, which will not be discussed in the present paper, all of the changes deal with the phenomena broadly known as starch gelatinization.

[a] Presented at the Tenth Annual Meeting of the I. F. T., Chicago, Illinois, May 23, 1950.

## Cold Slurry Flow-Time

The chemical and heat treatment which starch receives during the starch production operations has a marked effect on the characteristics of the starch. One manifestation of heat treatment during drying resulting in a slight gelatinization is an increased ability of the starch to absorb or hold water. The determination of the flow-time of a starch-water slurry under specific conditions is a measure of the absorption.

### Test Procedure[b]

A starch of known moisture content is mixed in a 600 ml. glass beaker with water at 85° F. (29.4° C.) in the proportions required to attain the desired concentration in the slurry. The mixture is agitated for five minutes by means of a stainless steel, propeller type agitator driven at 30 r.p.m. The slurry is transferred to a standard funnel (Figure 1) up to a height 5 mm. from the top of the funnel. The time required for 100 ml. to flow into a 100 ml. graduate is measured with a stopwatch.

[b] This method is a modification of a test procedure employed by the Hubinger Co., Keokuk, Iowa and recommended to us for starch evaluation.

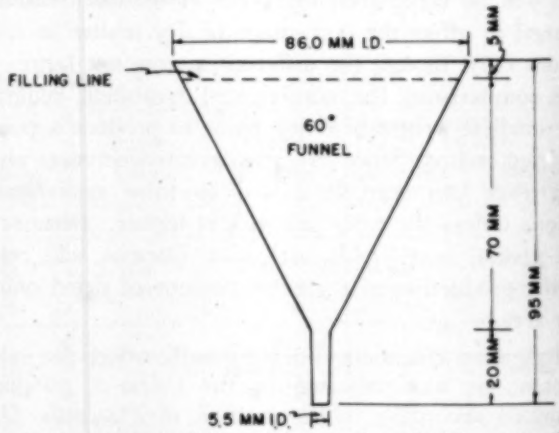


Fig. 1. Apparatus used for cold slurry flow time determination.

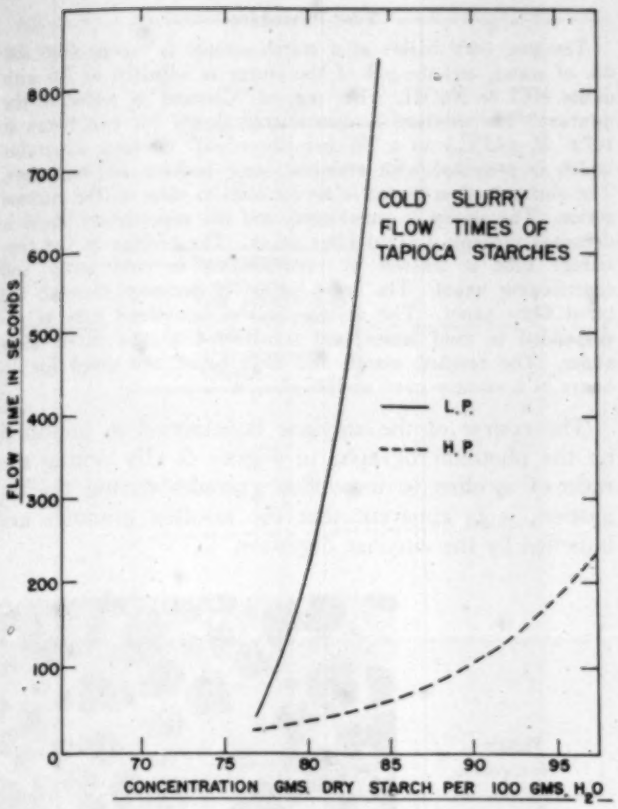


FIG. 2. Viscosity curves for Brazilian tapioca starch.

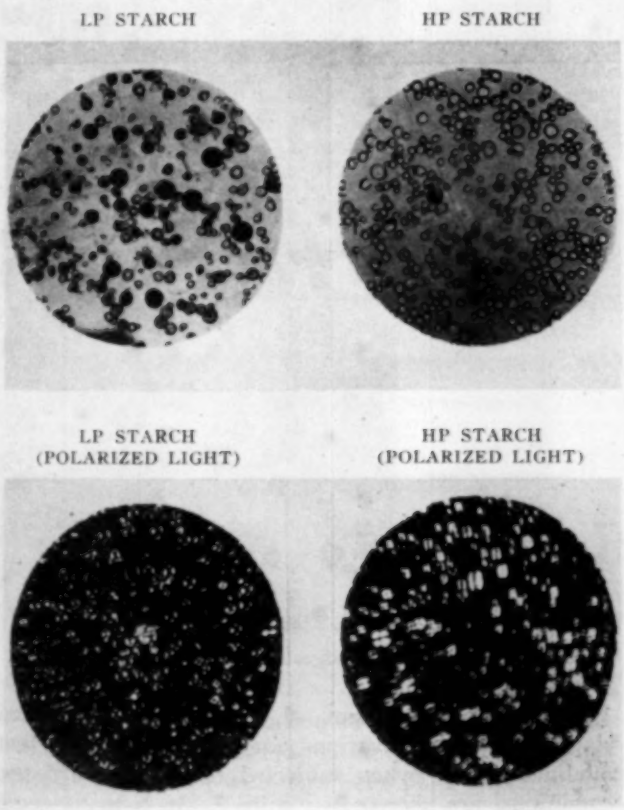


FIG. 3. Photomicrographs of starches used for cold slurry flow time.

By determining the flow-time at different starch concentrations, a curve is obtained which is characteristic of the starch sample. Such curves are given for two samples of Brazilian tapioca starch in Figure 2. Photomicrographs (Figure 3) of these two starches reveal that sample LP contains more slightly swollen starch granules than sample HP. This sample also contained more starch granules which, under polarized light, showed a faded Maltese cross or no Maltese cross. The small amount of swollen starch is probably responsible for the greater absorption of water by the starch, resulting in a marked increase in the flow-time of the starch slurry. This water absorption characteristic is important in many processes involving the pumping or manipulation of heavy slurries of starch in water at temperatures below that of gelatinization or prior to gelatinization. The absorption of water is important in those processes in which gelatinization takes place in the presence of a limited amount of water. Under these conditions non-uniform absorption of moisture results in non-uniform gelatinization, since the gelatinization temperature of starch is a function of the amount of moisture available.

## Viscosity Change During Heating

The viscosity of a starch suspension changes upon heating due to the swelling, rupture and dispersion of the starch. Although the information obtained is similar in many respects, we prefer the Brabender amylograph instrument to the Corn Industries Research Foundation's instrument for control operations as well as for our research activities. The data discussed in this paper are consequently limited to those obtained on the Brabender instrument.

### Test Procedure for Tapioca Starch *

To a twenty-seven gram starch sample (dry weight basis) is added sufficient distilled water to bring the total weight to 477 gm. After mixing, the starch suspension is poured into the cup of the Brabender amylograph. The starch suspension is heated from 95 to 194° F. (35 to 90° C.) at a constant rate of 2.7° F. (1.5° C.) per minute. The temperature of 194° F. (90° C.) is maintained for 15 minutes. The starch slurry is then cooled at a constant rate of 2.7° F. (1.5° C.) per minute.

The marked viscosity changes taking place during the heating of the starch suspension are brought about mostly by physical modifications in the starch granule. These changes and consequently the viscosity changes differ with different starches. Figure 4 shows the amylograms for two samples of Brazilian tapioca starch.

The changes taking place during the heating of the starch slurry in the Brabender amylograph instrument are best explained by a study of photomicrographs of the starch suspension.

## Changes in Microscopic Appearance

The first photomicrograph (Figure 5) shows little or no visual change in the starch granule prior to the rapid increase in viscosity of the HP and LP starches. A comparison of the photomicrographs taken during

* If this procedure is used for other types of starch it will be necessary to use a different starch sample weight.

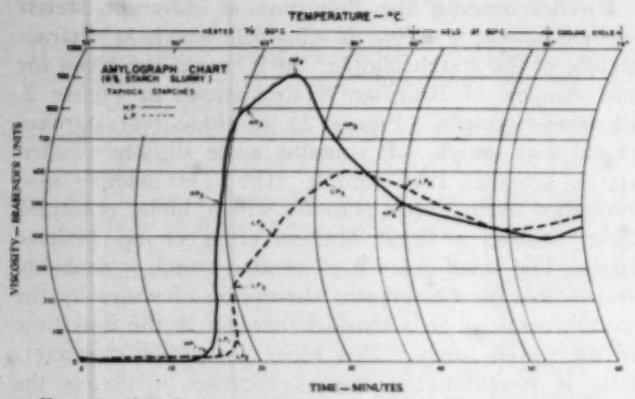


FIG. 4. Amylograms of two samples of Brazilian tapioca starches.

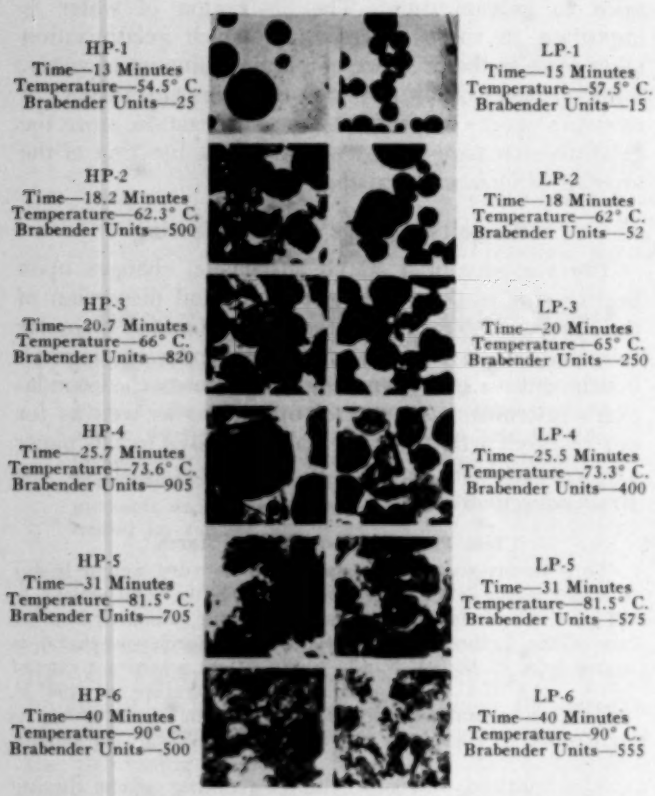


FIG. 5. Photomicrographs of amylograph samples.

the swelling of the granule suggests a mechanical explanation for the rapid increase of viscosity. The rapid swelling of the starch granule alters the flow characteristics due to the congestion of the distended granules. As the starch granules rupture and the starch is dispersed, the viscosity drops.

### Amylase Susceptibility

It is well known that the degree of gelatinization and starch granule damage has a marked effect on the rate of amylase action. In our work we have found that an empirical procedure using Clarase (a product manufactured by Takamine Laboratories) exhibits a marked difference in rate of liquefaction of heat modified granules and of unaltered starch granules. A study of the variables involved established the following preferred conditions for conducting the test.

### Test Procedure

Ten gm. (dry basis) of a starch sample is mixed with 200 ml. of water, and the pH of the slurry is adjusted to 5.6 with dilute HCl or NaOH. Fifty mg. of "Clarase" is added to the mixture. The mixture is then stirred slowly for two hours at 107.6° F. (42°C.) in a "Weber-Ehrenfield" mashing apparatus which is provided with stainless steel beakers and agitators. The slurry is then placed in an ice bath to slow up the enzyme action. The slurry is centrifuged, and the supernatant liquid is decanted through a tared filter paper. The residue in the centrifuge tube is washed by resuspending in cold water and centrifuging again. The wash water is decanted through the tared filter paper. The residue in the centrifuge tube is resuspended in cold water and transferred to the tared filter paper. The residual starch and filter paper are dried for 16 hours in a vacuum oven at 158° F. (70° C.).

The course of the amylase liquefaction is indicated by the photomicrographs in Figure 6. By noting the ratio of swollen to unswollen granules during the digestion, it is apparent that the swollen granules are liquefied by the amylase digestion.

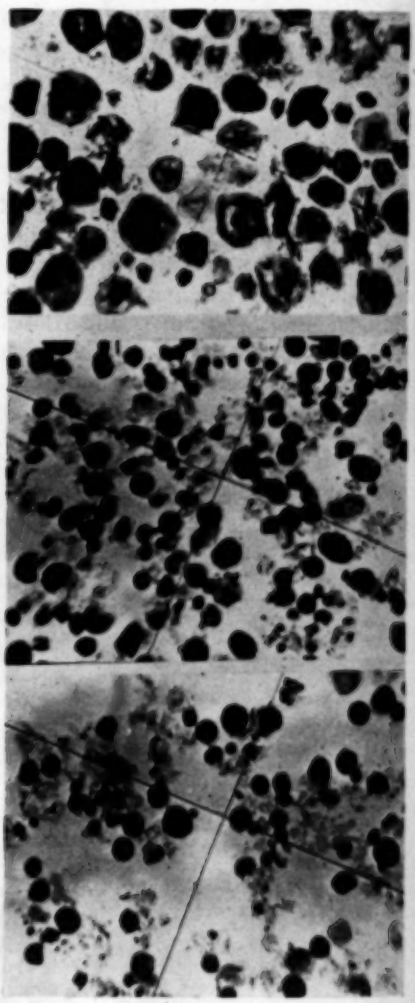


FIG. 6. Photomicrographs showing rate of amylase digestion.

The rate and extent of liquefaction of tapioca starches containing various amounts of raw and heat modified starch, when subjected to the standard test conditions, are shown in Figure 7. It is to be noted that in all cases studied the extent of liquefaction levels off rapidly. A digestion period of two hours is well

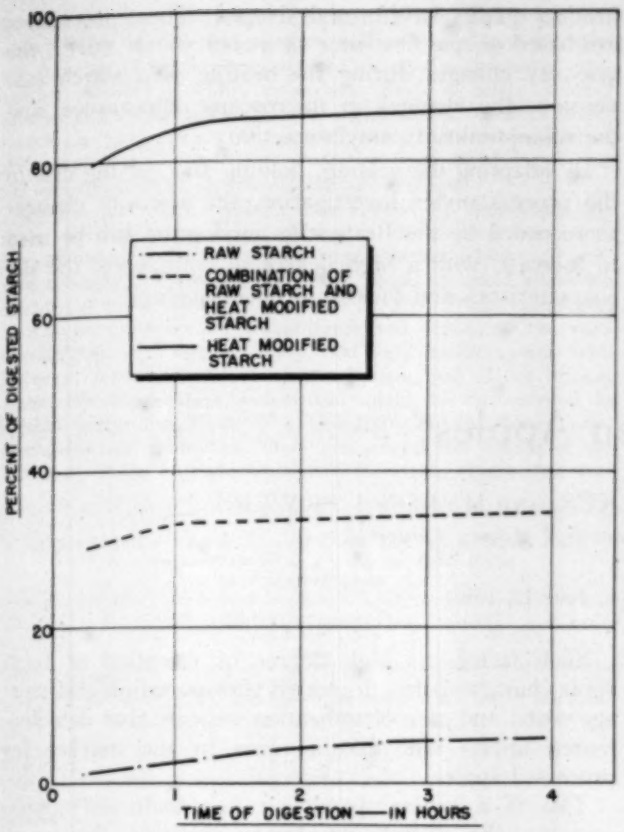


FIG. 7. Amylase susceptibility of tapioca starches.

within the plateau region. By making due allowance for the extent to which the raw starch is liquefied, it is possible to interpret the degree of liquefaction obtained in the standard test in terms of percent raw starch. The measurements are readily reproducible. The correlations which have been established between these analyses and the use characteristics of the various starches have been of great value. This is particularly true since photomicrographs are very difficult to evalute in quantitative terms.

The degrees of amylase susceptibilities of samples of tapioca starch taken during a Brabender amylogram are tabulated in Table 1.

TABLE 1

*Degree of Amylase Susceptibility of Amylogram Samples*

| Amylograph Curve Position | Raw Starch, Percent |
|---|---|
| LP-1 | 15.3 |
| LP-2 | 3.0 |
| LP-3 | 3.0 |
| LP-4 | 6.0 |
| HP-1 | 20.6 |
| HP-2 | 2.7 |
| HP-3 | 1.8 |
| HP-4 | 1.2 |

## Interpretation of Data

The microscopic observations and the enzyme susceptibility, combined with controlled plant experiments, form the sound basis for the interpretation of Brabender amylograms. The temperature at which the rapid swelling commences is clearly observed by the rapid rise of the curve. The minimum temperature at which rapid swelling starts is important in the control of many processes. The extent and rate of swelling of the starch are indicated by the height of the viscosity peak and the time necessary to reach it. This maximum or peak can be narrow and very sharp or broad, depending upon the rate of swelling and resistance of the starch granule to rupture. A starch giving a sharp, narrow viscosity maximum will require very close control of the heat treatment if a uniformly swollen starch granule is desired in the food processing. Conversely, a starch giving a broad viscosity maximum or plateau will not require as critical processing control in order to obtain uniformly swollen starch granules and consequently uniform product quality. To generalize, if minor processing variables are unavoidable and if uniform swelling is desired then (other things being equal) a starch giving a broad maximum viscosity or plateau will be most satisfactory.

The resistance of the swollen granule to full distention and rupture is reflected in the portion of the curve during which the starch is held at a high temperature. Resistance to "cooking out" or rapid loss of viscosity on further heat treatment, such as during the recipe use as a pudding or as a pie thickener, is often an important characteristic. The holding and cooling portions of the amylogram cycle are often related to such qualities.

It is believed that the procedures given will serve best if they are accepted as general procedures and are adapted to the particular case with respect to time and temperature relationships.

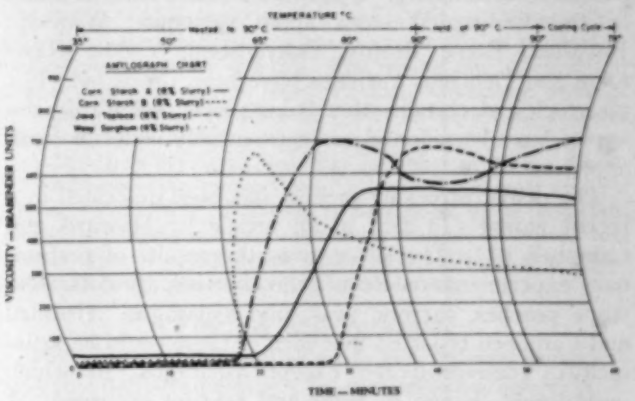


FIG. 8. Amylograms of various starch samples.

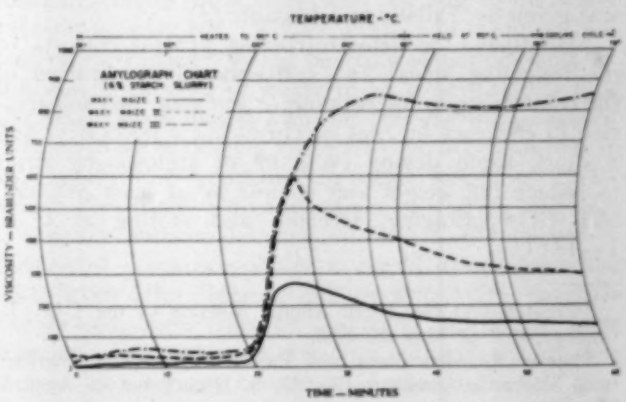


FIG. 9. Amylograms of three samples of waxy maize starch.

### Typical Brabender Amylogram Curves

Typical curves representative of some of the variations to be encountered with corn, waxy sorghum, Java tapioca, and waxy maize are given in Figure 8 and Figure 9. Detailed interpretation according to the criteria noted above will bring out many differences and valuable conclusions.

### Summary

Procedures for the evaluation of some starch characteristics related to processing in use and finished product quality have been developed. These procedures are based on the flow-time of a cold starch slurry, the viscosity changes during the heating of a starch suspension, the changes in microscopic appearance, and the susceptibility to amylase activity.

By adapting the heating, holding and cooling cyle to the process under investigation, the viscosity changes as recorded by the Brabender amylogram can be used to forecast, with a high degree of confidence, the use characteristics and finished product quality.

# Dehydrofrozen Apples[a]

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**Dehydrofreezing, a new food processing technique combining the advantages of dehydration and freezing, has been satisfactorily applied to many of the leading Western apple varieties. Details on enzyme inactivation, drying temperatures, reduction of weight and volume, effects of variety and maturity, packaging, and their advantages and adaptability to bakery and institutional uses are given.**

Dehydrofreezing, a new food processing technique combining the advantages of dehydration and freezing, has been satisfactorily applied on a small scale to many of the leading Western apple varieties. Winesap, Jonathan, Rome Beauty, Gravenstein, Yellow Newtown and Delicious varieties have been processed. For pie stock and certain other baking uses, dehydrofrozen apples have been found to be essentially equal to fresh apples.

The dehydrofreezing process has been described in a recent patent *(1)* and in an article by Howard and Campbell *(2)*. The latter gives the results of preliminary experiments on Royal Ann cherries, apricots, freestone peaches, carrots, peas, and asparagus. Howard and Campbell reported that each of these could be satisfactorily dehydrofrozen except asparagus, in which undesirable change in color and texture occurred. A detailed account of the research on dehydrofrozen peas was given by Talburt and Legault *(3)*.

Essentially, the dehydrofreezing process consists of the following steps: (a) conventional preparation of the commodity as for canning or freezing, (b) inactivation of enzymes by heat or chemicals if necessary, (c) a short, rapid drying cycle in an atmospheric drier to reduce the weight and volume by at least one-half, and (d) packaging, freezing and storing at 0° F. (—18° C.).

Such factors as high degree of retention of fresh apple characteristics, decreased transportation and storage costs, and ease of utilization indicate that dehydrofrozen apples will find a place in the market for processed apples.

This is a general paper on dehydrofrozen apples, covering the overall processing methods developed, properties, quality and uses of the finished product. Other more specific and detailed papers on enzyme inactivation and varietal effects, drying conditions, and economics of dehydrofrozen apples are to be published soon.

### Preparation

The apples are peeled, cored and sliced in conventional radial sections or wedges. Since the processing operation was set up batchwise in order to adapt it to available equipment, it was necessary to accumulate the prepared slices in a 1 percent salt solution until a drier load (about 40 pounds) was ready. Continuous operation, possible with other types of driers, would eliminate need for the salt-water bath.

Radial sections are not considered the ideal shape or size for dehydrofreezing, because the use of smaller pieces, such as segments of transverse slices or rings, reduces problems incident to enzyme inactivation, shortens drying time, and hastens reconstitution. However, most of the research has been conducted on the conventional radial slices, since they are so commonly used.

### Enzyme Inactivation

Apples, unlike many other fruits, contain sufficient air in the intercellular spaces to cause internal darkening when prepared slices are frozen and thawed or when they are slowly heated above 120° F. (48.9° C.). Since both of these treatments occur when apples are dehydrofrozen, it is necessary that oxidative enzymes in the center of the apple slice be inactivated as well as those on or near the surface.

The two usual methods of enzyme inactivation (by heat or chemicals) have been investigated. Results so far indicate that,

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[a] Presented at the Tenth Annual Meeting of the I. F. T., Chicago, Illinois, May 24, 1950.

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if small amounts of sulfur dioxide (25-50 p.p.m.) are not objectionable in the final product, sulfurous acid and its salts are superior to other chemicals and to heat as means of preventing darkening. This procedure gives a better colored product and avoids leaching losses incidental to steam or water blanching. Salt, citric acid, ascorbic acid, and combinations of these have not given adequate protection from darkening during the subsequent steps of dehydrating and freezing.

Sulfites and sulfur dioxide are applied by immersing the apple slices in an aqueous solution of the desired compound. The minimum contact time and concentration which will prevent subsequent darkening are used, so as to avoid excessive amounts of sulfur dioxide in the final product. It has been found that these minimum immersion times and concentrations vary considerably with apple variety and to a lesser extent with maturity. The temperature of the dipping bath is not critical within the temperature range that might be encountered in normal operations, 60-90° F. (15.6-32.2° C.). Minimum concentrations and immersion times for several lots of apples are shown in Table 1. Examination of this table shows that sulfurous acid penetrates apple tissue much more rapidly than sodium bisulfite (acidified to pH 3 with citric acid). Thus by the use of sulfurous acid instead of acidified sodium bisulfite solution in the dipping bath, it is possible to reduce the immersion time from 20 to only 3 minutes without increasing the concentration of the solute. The use of sulfurous acid, with resulting shorter immersion times, is recommended for Winesap, Yellow Newtown, and Delicious varieties, in order to minimize leaching losses in the dipping process. Certain soft varieties, such as Gravenstein and Jonathan, have been so permeable to sulfur dioxide that short immersion times were possible with acidified bisulfite solutions.

TABLE 1

*Minimum Sulfur Dioxide Concentrations and Times Required for Enzyme Inactivation in Processing Apple Slices for Dehydrofreezing*

| Variety | $NaHSO_3$ (adjusted to pH 3 with citric acid) | | $H_2SO_3$ | |
|---|---|---|---|---|
| | Concentration (as percent $SO_2$) | Dip time (minutes) | Concentration (as percent $SO_2$) | Dip time (minutes) |
| Pippin | 0.4 | 20 | 0.4 | 3 |
| Delicious | 0.4 | 20 | 0.6 | 2 |
| Gravenstein | .... | .... | 0.2 | 3 |
| Gravenstein | .... | .... | 0.4 | 0.75 |
| Jonathan | 0.4 | 2 | .... | .... |
| Winesap | .... | .... | 0.6 | 2.5 |

In all laboratory operations it was found possible to set the immersion time at three minutes and vary the concentration of the sulfurous acid in the dipping bath so as to obtain the minimum treatment for preventing darkening. Concentrations of sulfur dioxide in the dipping bath in excess of 0.6 percent (6,000 p.p.m.) should be avoided owing to the high partial pressure of sulfur dioxide. This results in excessive losses of sulfur dioxide from the solution and noxious fumes around the bath.

For certain uses, as in baby foods or in remanufacture, where canning is involved, small quantities of sulfur dioxide in dehydrofrozen apples may not be permissible. In such cases enzymes may be inactivated by conventional steam or water blanching procedures.

Apple slices, after treatment for enzyme inactivation, go directly from the blancher or sulfiter to the drier. No holding period is necessary to allow penetration of sulfur dioxide and if heat is used to inactivate enzymes, the hot slices may go directly to the drier without cooling.

## Drying

The slices, blanched or treated with sulfur dioxide to prevent enzymatic darkening, are partially dehydrated in an atmospheric drier. Drying conditions are not critical for blanched apples as long as excessive temperatures, which may cause heat damage, are not used; 220° F. (104.4° C.) can be safely used where extent of dehydration does not exceed 50 percent of original weight. However, in drying slices treated with sulfur dioxide, conditions must be carefully controlled, since the final sulfur dioxide content, which should be kept near its threshold value, is determined to a large extent by the wet and dry bulb temperatures used in drying. In addition, as mentioned in the previous section, sulfur dioxide must penetrate to the center of the slice before the piece temperature rises above 120° F. (48.9° C.); otherwise center darkening will occur.

Drying conditions are controlled so that sulfur dioxide rapidly penetrates the apple tissue in the initial stages of drying and is almost entirely dissipated from the slices by the time the short drying cycle (30-60 minutes) is complete. Generally high humidities and high wet-bulb temperatures result in rapid sulfur dioxide penetration and low residual sulfur dioxide; low humidities and low wet bulb temperatures result in slower penetration and higher residual sulfur dioxide in the partially dried slices. By properly controlling drying conditions 200° F. (93.3° C.) dry bulb and 150° F. (65.6° C.) wet bulb temperatures the sulfur dioxide content in apple slices can be reduced from an initial value of 300-500 p.p.m. to 20-40 p.p.m. (fresh slice basis) in the final product. This amount of sulfur dioxide permanently protects the dehydrofrozen apples from subsequent darkening.

Cabinet and tunnel-type driers using cross-flow air with velocities from 500 to 900 linear feet per minute have been successfully used in the partial dehydration step. Dry and wet bulb temperatures as high as 220° F. (104.4° C.) and 170° F. (76.7° C.), respectively, can be used without harming the product where dehydration is not in excess of that required to reduce the weight by one-half. The drying rate is rapid and almost linear up to this point. Further dehydration proceeds at a progressively slower rate and must be carried out at lower temperatures in order to avoid heat damage.

Where tray drying is used, tray loadings should not exceed 1.5 to 2 pounds per square foot in order to obtain more uniform drying. Uniformity of drying is considered to be important though not highly critical. Continuous multiple-belt driers and certain types of rotary driers should be suitable for this operation and should reduce labor costs considerably.

## Freezing and Packaging

Freezing and packaging costs are reduced considerably by dehydrofreezing. In the previous dehydration step, where the weight of the fresh slices is reduced by one-half, considerably more than one half of the water present is removed. Power costs and required refrigeration capacity would be reduced considerably by the smaller amount of water to be frozen in this type of product as compared with conventional frozen apples.

Savings in packaging costs may be accomplished in two ways: 1. By packing a greater weight of apples (fresh slice basis) into a container of a given size than is possible without dehydration, and 2. By the use of lower-cost containers since no liquid drains from the slices even after freezing and thawing. The partially dehydrated slices can be packaged before or after freezing. For maximum economy (to pack the greatest weight into a given container) packaging should precede freezing, since the unfrozen slices are soft and

pliable and pack closely into the container. In this state, it has been found that 50-60 pounds (fresh slice basis) of apples can be packed into a 30-pound can. When frozen before packaging, about 25 percent fewer apples can be packed into this size of container. The latter method of packaging, though more expensive, may be desirable for certain uses where individually frozen pieces are required.

### The Product

Dehydrofrozen apples, dried to 50 percent weight reduction, are reduced in size also by one-half, without appreciable change in the general appearance of the slices. These are quite attractive and are not shriveled or misshapen and do not have a dried-apple appearance. They are permanently protected against darkening and contain 20 to 40 p.p.m. sulfur dioxide (fresh weight basis). They can be thawed and held at 75° F. (23.9° C.) for several days without untoward effects and can be held for a week or longer at 32° F. (0° C.).

The thawing period is much shorter than that for conventional frozen foods. A 30-pound can will thaw in a few hours to the point where the slices separate freely. Absence of leakage from the thawed slices is a considerable advantage to the baker. In reconstituting for pie filling, a short soaking period of about one hour is sufficient for most uses. A direct cook, with all filling ingredients, of less than five minutes may also be used.

The permissible extent of dehydration is rather difficult to determine and may vary for different final uses. Dehydration in excess of 50 percent weight reduction (up to 60-65 percent) does not particularly change the organoleptic or rehydration characteristics of the resulting product. However, as dehydration proceeds beyond that required to reduce weight by 50 percent, the slices become progressively more collapsed and wrinkled. This may make the product less desirable for some uses.

Varieties that are excessively soft or lack in acid may be dehydrofrozen with calcium salts or rehydrated with acidulated water in order to correct these defects.

### Utilization

Utilization of dehydrofrozen apples, at least initially, is likely to be confined to institutions such as bakeries and restaurants. Considerable work has been done to evaluate use as pie stock for both wholesale and retail bakeries. Results of these bakery trials showed dehydrofrozen apples to be quite satisfactory for large or small operations, and readily adaptable, with only minor changes in procedure, to any of the commercial methods employing either fresh, frozen, or canned apples. No additional equipment is required.

The flavor and texture of dehydrofrozen apples, evaluated in pie, are considered similar to those of fresh apples. For at least a few months out of the year dehydrofrozen apples are superior to slices from long-storage, fresh apple in both texture and flavor.

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# Relationships Between the Amount and Composition of Press Fluid, Palatability, and Other Factors of Meat

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**No relationship was found in beef between percentage of press fluids and scores for quantity of juice. There was a direct curvilinear relationship between percentage of fat in press fluid and scores for quantity and quality of juice. Percentage of press fluid tended to decrease with increase in its fat content. Consistent relationships between these factors were not found in lamb, mutton, and chevon.**

### Introduction

Quality and quantity of juice are among the most important properties that contribute to the palatability of meat. The limitations of the subjective method of determining these palatability factors are well recognized and have been adequately described. Objective methods are needed in meat research, but progress in that direction has been slow because of the extreme complexity of the juiciness factors.

In connection with breeding, nutrition, and meat investigations in the U. S. Bureau of Animal Industry at Beltsville, Md., carcasses of animals are examined for physical, chemical, and palatability characteristics. This report deals with relationships between palata-

[a] Presented at the Tenth Annual Meeting of the I. F. T., Chicago, Illinois, May 24, 1950.

[b] The authors wish to give credit to H. Slofsky who determined the correlation coefficients, R. Berg, H. Tucker, and R. Bechtold for assistance in certain phases of the chemical work and to W. Kauffman who determined the fat content of the press cakes, total edible portion of the ribs, and the rib eye muscles.

bility factors of juiciness, amount and fat content of press fluid, age, breed, carcass grade, and intramuscular fat of beef, lamb, and mutton.

## Review of Literature

Amount of juice has been defined by the Committee on Preparation Factors *(7)* as the relative quantity of juice judged in the act of chewing, or measured by mechanical means. Several accurate mechanical expression methods have been proposed and employed. However, relationships with scores for quantity of juice have been inconsistent. On the whole, subjective juiciness and the amount of press fluid do not appear to represent quite the same thing.

Using the pressometer devised by Child and Baldelli *(5)* at 250 p.s.i.g., Smith *(15)*, Satorius and Child *(14)*, and Hardy and Noble *(9)* reported correlations of 0.1, 0.31 (not significant), and 0.32 to 0.51 (highly significant), respectively, between scores for quantity of juice and the amount of expressible juice. Clark and Weatherby *(6)* used a hydraulic press at 10,000 p.s.i.g. at different temperatures and found no significant correlation. Using the same type of press, Tannor, Clark, and Hankins *(16)* found a correlation of 0.60 when a pressure of 9,800 pounds at 50° C. (122° F.) was used. Furthermore, when results from meat at different stages of doneness were compared, a correlation coefficient of 0.9 was found. Hall and co-workers *(8)* subjected ground raw and cooked meat to 4,000 p.si.g., and found no relation between press fluid and palatability. However, Wanderstock and Miller *(17)*, using the same pressure on raw beef rib eye muscle, found that in general the more finish a carcass carried the smaller was the amount of press fluid.

Quality of juice has been defined by the Committee on Preparation Factors *(7)* as the relative degree of richness and smoothness of the meat juices and is believed to depend on the concentration in the juice of meat solids, including fat. Many workers including Smith *(15)* and Satorius and Child *(14)* have found a close direct relationship between quantity and quality of juice. The latter workers found a correlation of +0.8. It is perhaps significant that in this work they found no important correlation between score for quantity of juice and press fluid. Therefore, it is possible that palatability factors of juiciness are influenced not so much by amount of juice as by its composition.

There is a general belief that high finish in an animal improves the quality and palatability of its meat. Branaman, Hankins, and Alexander *(3)* reported that quality and quantity of juice show a progressive increase in meat with an increase in intra-muscular fat. Hayes *(10)* found highly significant differences, due to carcass grade of beef, in quality and quantity of juice as well as the other palatability factors. Barbella, Tannor, and Johnson *(2)* after evaluating data from 728 cattle of different breeds and ages concluded that there was a significant direct relationship between age, ether extract of 9-10-11 rib cut, and scores for quality and quantity of juice. Scores for quantity of juice increased rapidly with increase in fatness to 22.5 percent and more slowly to 42.5 percent after which there was no apparent effect.

Wanderstock and Miller *(17)* found that beef with a higher finish scored higher in quality and quantity of juice. Maw *(12)* expressed the opinion that the degree of internal fat laid down in poultry determines the quality and moistness of the flesh.

In mature animals there is little variation in the chemical composition of muscle tissue of cattle, hogs, and sheep on a fat-free basis. However, Moulton *(13)* has shown that the protein-moisture ratio decreases as an animal approaches maturity, and Chatfield *(4)* and Hoagland and Powick *(11)* gave evidence that this ratio also decreases with increase in degree of fatness. Although small decreases in the amount of moisture per unit of protein appear to occur on fattening, the chief change which takes place involves a dilution of the moisture and protein of the lean by the addition of fat, weight for weight.

Apparently change in amount of protein is not of much significance. Hall and co-workers *(8)* pointed out the remarkable constancy of the sum of the amount of fat and moisture found in the rib eye of cattle of the same age which had a considerable variation in fat content. In view of these facts, the main change when an animal is fattened is the replacement of moisture with fat. Therefore, in meats cooked to the same state of rareness the potential amount of fluid would be expected to be about the same regardless of difference in fat content. However, it seems reasonable to suppose that the fat would be more difficult to remove than the moisture it has replaced. Moreover, the presence of intra-muscular fat might be expected to hold back some of the moisture that would otherwise be pressed out as juice. Accordingly, a cut of high intra-muscular fat content should tend to yield less press fluid than one of low fat content.

## Experimental Procedure

The investigation involved 50 dual-purpose and 47 beef-type Shorthorn steers; 61 crossbred lambs, 27 purebred lambs of various breeds; 27 mature Karakul sheep, and 11 goats of Toggenburg and mixed breeding. All animals were fed a well-balanced ration. The steers were slaughtered at approximately 500 or 900 pounds, and the sheep and goats at various ages, weights, and degrees of fatness. In the group of purebred lambs, paired left and right legs of each animal were studied; while for the other lambs, mutton, and the goats only one leg from each animal was examined.

After storage at 38° F. (3.33° C.) for 10 days, left 9-10-11 rib cuts of the steers, and lamb, mutton and chevon legs were roasted in a ventilated electric oven at 302° F. (149° C.) to an internal temperature of 140° F. (60° C.) for beef and 156° F. (69° C.) for sheep. Sampling and palatability scoring on a 1-7 point scale were performed according to the method developed by the cooking committee of the Cooperative Meat Investigations project *(1)*. Juice was expressed at 9,800 p.s.i.g. at 50° C. (122° F.) according to the method of Tannor et al. *(16)*. After expression, the collected juice was extracted three times with petroleum ether in a mojonnier flask. The solvent was removed from the combined extract on the steam bath with a jet of nitrogen gas. The fat residue was dried to constant weight at 98° F. (36.7° C.) in a vacuum oven. Percentage of fat in the press fluid was calculated on the basis of the loss in weight of the meat samples rather than on the weight of the collected press fluid. In some cases the press cake was analyzed for fat. The raw right 9-10-11 rib cuts of the steers were analyzed for percentage of fat of the total edible portion and rib eye muscle.

## RESULTS

### Press Fluid

The Tannor et al. *(16)* method of pressing meat gives accurate press-fluid percentages, but it is not adapted to the quantitative collection of press fluid. Losses averaged about three grams, of which about one gram was caused by evaporation. Owing to differences in the size of sample and amount of press fluid therefrom, the percentage loss of press fluid varied considerably. This is shown in Table 1.

The composition of the collected press fluid, because of its non-homogenous nature, was affected by mechanical losses. The juice became richer in fat as the pressing continued, and in a sample of high intramuscular fat content the final portion was often largely fat. Therefore, differences in mechanical and evaporation losses, together with differences is sample size and juice content, made the fat content of the collected juice not strictly representative. However, it was sufficiently so to be usable. Percentage of fat content was, therefore, calculated on the basis of the loss in weight of the meat sample. There was, of course, a loss of fat and results were low, but they were assumed to be comparable.

### Distribution of Fat in Meat After Pressing

The amount of fat in the sample of meat before pressing was estimated from the fat composition of the press fluid, press cake, and loss in weight of meat sample and weight of meat sample. Table 1 shows considerable variation, among the animals in the percentage of total fat that was pressed out.

Generally, with an increasing amount of fat in the meat sample there was an increase in the percentage of fat expressed. However, there were dips in the upward swing of this percentage. Moreover, the data indicate that, on the average, the percentage of total fat expressed was lower for the beef-type steers than for the dual-purpose steers. The variations may have been due to differences in the way the fat was deposited in the tissue. Factors such as sampling and losses in pressing make this difficult to evaluate. Furthermore, data in Table 2 on paired lamb legs indicate that these factors can be responsible for large differences in the percentage of total fat expressed from samples of cuts from the same animal.

### Effect of Finish on Scores for Quality and Quantity of Juice and Press Fluid and Its Fat Content

Table 3 shows mean values for juiciness, percentage of press fluid and its fat content, carcass grade, and percentage of fat in the edible portion and rib eye of 9-10-11 ribs of 500- and 900-pound dual-purpose and beef-type Shorthorn steers. Percentage of press fluid was higher and scores for quantity and quality of juice were lower in the 500-pound steers than in the 900-pound ones. It appears that the scores for quality and quantity of juice are influenced by the amount of intramuscular fat and the fat content of the press fluid. Moreover, the results indicate that the percentage of

TABLE 1

*Distribution of Fat When Meat From Steers was Pressed*

| Item | Dual-purpose-type Steer No. | | | | | | | | Beef-type Steer No. | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | G-71 | G-66 | G-69 | G-56 | G-65 | G-78 | G-19 | G-21 | 624 | 585 | 591 | 590 |
| | *percent* | *percent* | *percent* | *percent* | *percent* | *percent* | *percent* | *percent* | *percent* | *percent* | *percent* | *percent* |
| Fat in meat sample (calculated) | 0.77 | 0.85 | 1.01 | 1.09 | 1.32 | 1.46 | 2.63 | 5.29 | 2.35 | 4.64 | 5.63 | 8.36 |
| Total fat expressed | 8.82 | 10.00 | 33.00 | 29.79 | 22.41 | 24.62 | 19.64 | 38.45 | 5.35 | 19.72 | 17.94 | 26.73 |
| Fat in press cake | 1.13 | 1.20 | 1.18 | 1.24 | 1.72 | 1.80 | 4.50 | 5.59 | 3.79 | 6.75 | 8.22 | 10.89 |
| Fat in press fluid | 0.19 | 0.23 | 0.77 | 0.88 | 0.70 | 0.95 | 1.58 | 4.88 | 0.33 | 2.04 | 2.81 | 5.11 |
| Loss of press fluid in collecting | 14.21 | 31.45 | 11.14 | 27.11 | 14.21 | 16.43 | 14.02 | 19.46 | 11.43 | 13.91 | 14.24 | 12.38 |

TABLE 2

*Distribution of Fat When Meat From Paired Lamb Legs (Left and Right) was Pressed*

| Item | Left | Right | Left | Right | Left | Right | Left | Right | Left | Right | Left | Right |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | *percent* | *percent* | *percent* | *percent* | *percent* | *percent* | *percent* | *percent* | *percent* | *percent* | *percent* | *percent* |
| Fat in meat sample (calculated) | 2.80 | 2.90 | 3.10 | 2.40 | 3.33 | 3.76 | 7.39 | 3.54 | 4.22 | 4.04 | 4.21 | 5.30 |
| Total fat expressed | 6.37 | 20.08 | 13.23 | 17.45 | 14.89 | 25.14 | 41.89 | 25.19 | 30.81 | 16.72 | 21.35 | 39.11 |
| Fat in press cake | 3.97 | 3.22 | 3.84 | 3.33 | 4.73 | 4.16 | 6.53 | 4.03 | 4.77 | 5.39 | 5.18 | 4.76 |
| Fat in press fluid | 0.66 | 1.87 | 1.28 | 1.25 | 1.38 | 3.33 | 3.11 | 1.62 | 3.79 | 2.07 | 3.60 | 7.76 |
| Press fluid | 33.81 | 36.36 | 37.25 | 40.95 | 39.53 | 32.35 | 34.26 | 42.68 | 39.43 | 37.69 | 36.14 | 32.14 |

TABLE 3

*Mean Objective and Subjective Values for 500- and 900-Pound Shorthorn Steers of Beef and Dual-Purpose Types*

| Type and weight of steers | Animals | Press fluid | Fat in press fluid | Juiciness [c] | | Carcass grade [d] | Fat in edible portion of rib | Fat in rib eye |
|---|---|---|---|---|---|---|---|---|
| | | | | Quality | Quantity | | | |
| | *No.* | *percent* | *percent* | *score* | *score* | *score* | *percent* | *percent* |
| Dual-purpose, 500 lb. | 20 | 41.10 | 0.51 | 3.63 | 4.83 | 22.8 | 20.96 | 1.83 |
| Dual-purpose, 900 lb. | 23 | 39.14 | 1.85 | 4.28 | 5.20 | 20.4 | 28.45 | 2.66 |
| Beef, 500 lb. | 11 | 44.30 | 0.71 | 3.70 | 5.09 | 17.5 | 24.60 | 1.61 |
| Beef, 900 lb. | 34 | 40.64 | 2.88 | 4.64 | 5.48 | 12.4 | 38.04 | 4.32 |

[c] Juiciness was scored from 1 to 7, the former being the lowest score; the latter, the highest.
[d] The higher the score the lower the carcass grade.

press fluid tends to become lower with an increase in fat content.

### Correlation Studies on 9-10-11 Beef Ribs

Table 4 shows relationships in beef between the percentage of press fluid and palatability, carcass grade, and chemical composition factors. Percentage of press fluid was significantly related to only one of these factors; there was a highly significant inverse relationship with the percentage of fat in the juice. Relationships with percentage of fat in the edible portion of rib and the entire rib eye were negative, but low and not significant. It appears that with an increase in fat content of the meat there was some tendency toward a decrease in press fluid.

TABLE 4

*Correlation Coefficients Between Factors of Beef*

| Relationships | Correlation coefficient | Probable error | Probability value |
|---|---|---|---|
| Percentage press fluid to quantity of juice | −0.01 | ±0.07 | ..... |
| Percentage press fluid to percentage fat therein | −0.25 | ±0.06 | <0.02 |
| Percentage press fluid to carcass grade | −0.04 | ±0.07 | >0.7 |
| Percentage press fluid to percentage fat in edible portion of rib | −0.08 | ±0.07 | >0.4 |
| Percentage press fluid to percentage fat in rib eye | −0.11 | ±0.07 | >0.3 |
| Percentage fat in press fluid to quantity of juice | +0.22 | ±0.07 | <0.05 |
| Percentage fat in press fluid to quality of juice | +0.36 | ±0.06 | <0.01 |
| Percentage fat in press fluid to carcass grade | +0.54 | ±0.05 | <0.001 |
| Percentage fat in press fluid to percentage fat in edible portion of rib | +0.61 | ±0.05 | <0.001 |
| Percentage fat in press fluid to percentage fat in rib eye | +0.71 | ±0.04 | <0.001 |
| Quantity of juice to quality of juice | +0.45 | ±0.06 | <0.001 |
| Quantity of juice to percentage fat in rib eye | +0.30 | ±0.07 | <0.01 |
| Quality of juice to percentage fat in rib eye | +0.39 | ±0.06 | <0.001 |

Relationships between fat in the press fluid and the factors under consideration were all significant or highly significant. The indication is that the fat in the press fluid was closely related to the carcass grade, general fatness of the cut, and the amount of intramuscular fat. Evidently the fat content is at least one of the important factors that directly influence the scores for quantity and quality of juice. Correlation is probably considerably higher than indicated since the relationships appear to be curvilinear.

Figure 1 shows the relationship between percentage of fat in the press fluid and scores for quantity of juice. Data were condensed by dividing them into groups at three percent intervals of press fluid. Each of these groups was then divided into subgroups at 0.5 percent intervals of percentage of fat in press fluids, and the mean values of percentage of fat and scores for quantity of juice in each subgroup were plotted. These values are represented by the dots. Following this, the mean values in each 0.5 percent fat group were averaged and plotted as crosses. The resulting curve appears to indicate an increase in score for quantity of juice up to about two percent fat, after which there was little change with increase in fat concentration. If data

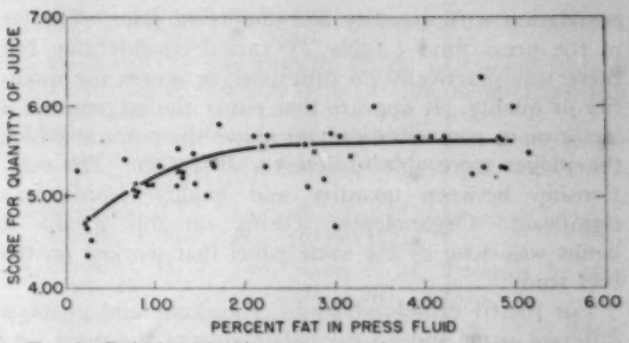


FIG. 1. Relationship between score for quantity of juice and percent fat in press fluid of beef.

around the curved part of the line in Fig. 1, that is, up to about 2.0 percent fat, are correlated, a coefficient of $+0.41 \pm 0.07$ ($N = 67$, probability $<0.001$) is obtained. The data around the remaining flat part of the curve have a correlation coefficient of $-0.13 \pm 0.13$ ($N =$ probability $>0.5$). The curve of the relationship with quality of juice is similar.

As shown in Table 4, the relationship between quality and quantity of juice was fairly high and highly significant. There was a highly significant relationship between the two palatability factors and the percentage of fat in the rib eye. Quantity and quality of juice were closely associated and evidently directly related to the amount of intra-muscular fat. These relationships to intra-muscular fat content are no doubt similar to that shown in Figure 1.

### Correlation Studies on Lamb Legs

As shown in Table 5, among the 54 paired lamb legs, there was a significant correlation between percentage of press fluid and quantity of juice. In this group, fat in the press fluid was not related to a signficant extent with percentage of press fluid. There was no important

TABLE 5

*Correlation Coefficients Between Factors of Lamb Legs*

| Relationships | Correlation coefficient | Probable error | Probability value |
|---|---|---|---|
| **54 Paired Legs of Purebred Lambs** | | | |
| Percentage press fluid to quantity of juice | +0.31 | ±0.08 | <0.05 |
| Percentage fat in press fluid to percentage press fluid | −0.21 | ±0.09 | <0.2 |
| Percentage fat in press fluid to quantity of juice | −0.08 | ±0.09 | <0.6 |
| Percentage fat in press fluid to quality of juice | +0.11 | ±0.09 | <0.5 |
| Quantity of juice to quality of juice | +0.34 | ±0.08 | <0.02 |
| **61 Left Legs of Crossbred Lambs** | | | |
| Percentage press fluid to quantity of juice | +0.01 | ±0.09 | >0.9 |
| Percentage press fluid to carcass grade | +0.23 | ±0.08 | <0.1 |
| Percentage fat in press fluid to percentage press fluid | −0.09 | ±0.09 | <0.6 |
| Percentage fat in press fluid to carcass grade | +0.33 | ±0.08 | <0.01 |
| Percentage fat in press fluid to quantity of juice | −0.07 | ±0.09 | <0.7 |
| Percentage fat in press fluid to quality of juice | −0.08 | ±0.09 | <0.6 |
| Quality of juice to quantity of juice | +0.63 | ±0.05 | <0.001 |
| Quality of juice to carcass grade | +0.31 | ±0.08 | <0.02 |
| Quantity of juice to carcass grade | +0.19 | ±0.08 | <0.2 |

correlation with quantity and quality of juice. The fat in the press fluid (Table 2) varied considerably but there was practically no difference in scores for quantity or quality. It appears that either the fat was not a factor or its concentration was above the point at which the judges were able to detect a difference. The relationship between quantity and quality scores was significant. Organoleptic scoring on this group of lambs was done by the same panel that worked on the beef study.

For the 61 crossbred lambs, Karakuls, and goats, a different panel judged the palatability of the meat. As may be seen in Table 5, in contrast with the previous group of lambs, in the crossbred lambs, there were no significant relationships between press fluid and the other factors under consideration. However, in agreement with the other group, there was no significant relationship between percentage of fat in the press fluid and percentage of press fluid or scores for quantity or quality of juice. There was a highly significant relationship with commercial grade of carcass.

The quality and quantity of juice were related to a highly significant extent. Quality of juice was also significantly related to carcass grade.

### Karakul Sheep and Goats

The 27 Karakul sheep, ranging from one to eight years of age, had virtually no variations in scores for quality and quantity of juice, although the percentage of fat in the juice increased with age. Percentage of press fluid varied as much as 10 percent, but there was no relation to age.

The 11 goats from which legs were tested varied in age from one to four years. There was no consistent difference in scores for quantity of juice although the quality of juice scores increased somewhat with age. Percentage of fat in the press fluid tended to increase with age, while percentage of press fluid decreased.

### Discussion of Results

It would appear that a great deal of the disagreement in the literature with respect to relationships between scores for quantity of juice and amount of press fluid must be due to differences in interpretation of juiciness. Hall et al. *(8)* state that quantity of juice is one of the most difficult palatability factors to differentiate from other factors. Yet it may be that these factors are to some extent a part of the quantity of juice factor, and it is neither correct nor desirable to analyze this factor too objectively.

If meat is cooked to a state of doneness which involves no serious loss of moisture, a cut with low intramuscular fat should yield a little more press fluid than one of high fat content, chiefly because of the difficulty of removing fat and its tendency to hold back the moisture. Therefore, in view of the universal belief and much evidence that meat from a fattened animal is more juicy and palatable than meat from one not fattened, there seems to be no strong foundation for the opinion that the amount of press fluid should represent scores for quantity of juice.

The part played by moisture in the juice is no doubt important, and if it should fall below a certain, as yet undetermined level, the contribution of the fat to palatability might be lessened. If two meat samples differing in intra-muscular fat content should be cooked to a state of doneness at a temperature producing a serious moisture loss, then the press fluid would be less from the cut low in intra-muscular fat and there should then result a direct relationship between percentage of press fluid and scores for quantity of juice.

Fat adds flavor, resulting in stimulation of the saliva, thus increasing the impression of juiciness, richness and smoothness. It coats the mouth, causing a lasting impression of moistness during the chewing process.

The experimental results on beef appear to agree with the above reasoning. However, the data on lamb, mutton, and chevon (goat) legs were contradictory, and on the whole indicated no consistent relationships between subjective and objective tests.

Correlation coefficients between subjective and objective tests in beef though significant or highly significant, were rather low. It is not at present possible to determine whether this is due to the apparent curvilinear relationships between percentage of fat in the press fluid and scores for quantity and quality of juice, some other factor or factors, or to the well-known unreliability of subjective tests.

Collection of the data was over a period of four years. During the work on the lamb legs there was an unavoidable change in organoleptic panels. Possibly this accounts for some of the inconsistencies in the relationship between subjective and objective tests for quantity of juice. It seems worthy of note that scores for quantity of juice of the first panel showed no correlation with amount of press fluid in beef and a significant correlation in the paired lamb legs.

### Summary

Data on 97 beef rib samples indicated the percentage of press fluid was not significantly related to scores for quantity of juice. Apparently with an increase in percentage of fat in the press fluid as the result of more intramuscular fat, there was a tendency for the percentage of press fluid to decrease, and the scores for quantity and quality of juice to increase. Relationships between percentage of fat in the press fluid and juiciness appeared to be curvilinear, with the result that after about two percent fat content was reached there was little change in score.

Data from 115 lambs and sheep and 11 goats were contradictory and inconclusive. On the whole, there appeared to be no significant relationships between subjective and objective methods of assessing juiciness factors in the lamb, mutton, and chevon studied.

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# Industrial and Legal Viewpoints

## Chemical Agents and Residues in Foods: The Viewpoint of the Container Manufacturer[a]

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**Residues of agricultural chemicals or chemical agents that are the current concern of the Food and Drug Administration are not contributed to packaged foods by their containers. But occasionally an obscure flavor change in a packaged food has been traced to the container.**

**The flavor pick-up has been found to be most pronounced in fatty foods, and has even been encountered in cereals and tea. Such flavor control problems arise in flexible packages or semi-rigid containers with paperboard bodies, and stem from a variety of sources, all of them obscure and difficult to trace. Wrong types of printing inks, wrong plasticizers, contaminated or musty scrap paper, bactericidal agents used in paper mills to prevent slime bacteria, and the like have been known to be the cause of off-flavors, and in very rare cases have caused foods to be inedible.**

**The problem of preventing these off-flavors without incurring excessive container costs requires cooperation between all parties concerned, plus systematic inspection of incoming packaging supplies.**

Chemical agents and residues in packaged foods are not often the same sort of problem for the manufacturer of containers as they are for the farmer, the food technologist, the law and its enforcement officers. Problems exist, of course. And, admittedly the subject is sometimes controversial. But up to now, nobody has tried to keep me from discussing the subject. Which has been a bit of a disappointment to me, for my previous experience has taught me that the very existence of an attempt to keep my mouth closed is a sure guarantee of a lively audience interest!

### Procedure

Rather than to assume that I was well informed on what the container manufacturer thinks about my subject, the problems of chemical agents and residues in foods, I asked him what he thought. Then I questioned more than 100 food processors about this same aspect of the problem, lest there be any container manufacturers who might be reluctant to reveal their problems to me. Not content with that, I then went to a considerable number of regulatory organizations for their ideas. And as a still further precaution I went to research organizations, — some impartial and some possibly partial. In all, I attempted to ascertain the problems of the container manufacturer on this subject by sending out upwards of 750 inquiries.

The following brief remarks are the result of the responses to the foregoing inquiries, and full credit should be given to my many friends and collaborators who have shared their experience and knowledge with

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me. As you may surmise, if you have had any experience in the field, some of the experience in this aspect of our problem has been gained at great cost and great industrial sorrow. Hence it is confidential as to source. We should be grateful, however, to those who have revealed their troubles in order that all may benefit and thereby avoid repeating their painful experiences.

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When we analyze my part in this symposium, it is obvious that the chemical agents and residues in foods that get into the container because they were on—or in—the food material, or were put into the food by the processor, are not the responsibility of the container manufacturer. He did not put them there. But naturally the container manufacturer will be very sympathetic with any of his customers who face problems of this type, especially those customers whose products have been libelled and seized by regulatory officers because of the presence of prohibited chemical agents and residues.

In a few instances, usually isolated ones, the container manufacturer may be technologically concerned as well, should the foreign matter be the cause of chemical attack on the container. Such an instance occurred many years ago when lime-sulpher spray residues found their way into certain canned fruits and caused chemical reactions with the metal containers. These were of very great interest to can manufacturers for, in those remote days, it was the usual custom to blame the container manufacturer for practically every problem of a technological nature.

While the container manufacturer has only an indirect responsibility for the reactions of materials introduced with the foods into his containers, he does, however, have a very important responsibility for foreign chemicals that get into the food from the container itself. While none of these mishaps in recent years are matters of public health, they are nevertheless very important matters from the viewpoint of quality in the food, its consumer acceptance, and especially of quality control.

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In reviewing the problems I first want to orient you on packaging, then cover the more recent history of the problems, and finally sum up where we stand today.

Among students of packaging all forms of unit packages (the package that is in contact with the product and is generally the unit of consumer purchase) are either rigid or flexible. While I have never seen any official definition of a rigid container, by common consent rigid containers include the following:

Cans, whether metal or fibre or metal ended fibre
Drums, steel and fibre
Kegs and barrels, both metal and wood
Glass containers, bottles, jars, jugs, carboys
Ceramic ware

Flexible containers, as the term implies, usually refer to packages made from:

Paper
Films, either plastics or regenerated cellulose
Metal foils
Textiles
Combinations of the foregoing

In packaging circles there is a sort of twilight zone between rigid and flexible packages. In this twilight zone we find both corrugated and solid fibre containers and their proper classification is still a moot question. Some well informed persons aver that they are rigid containers. Others, including myself, maintain they are flexible containers.

In a discussion of this sort it is not possible to include all possible information, or even to high-light all the existing information regarding foreign substances that might get into a packaged food via the container. Therefore, after dealing with the very limited public health aspects of the problem, I am going to concentrate on the angles or aspects of flexible container packaging which are of primary importance to food technologists. These are important from the viewpoint of quality control and flavor control,—not from the public health angle.

The hazards to public health, where the container itself is concerned, are of historic interest only. Except for a few imported foods I do not know of any packaged foods where there is a hazard to public health today as far as the package itself is responsible.

Among the imported items that may be suspect are the following:

1. Jams and sardines in cans with floated soldered seams instead of the conventional double seam in use in the U. S. A. Here the considerable areas of lead-containing solder in contact with the food may lead to a hazardous degree of lead contamination.

2. Tea chests lined with lead foil may contribute lead contamination to the tea by the friction of contents against the liner which will rub off in measurable quantities.

Among domestic sources of foreign or extraneous chemicals from the rigid container where there has been also a public health hazard the following may be cited:

1. The easily removable lead contamination of maple syrup which comes from terne plate buckets or tin plate buckets that have been painted with white lead paint to prevent their rusting. These buckets are used for sap collecting and are not really industrial packages. This lead hazard is largely a thing of the past.

2. Cheap pottery packages that have been given a lead glaze in the course of their manufacture may contribute dangerous quantities of lead to a food held in them. Their use is so rare that potteries which make them are scarcely to be considered as manufacturers of food packages. As a matter of historical record it may be said that such ceramic manufacturers as have produced lead-glazed jars have been most cooperative with regulatory officials and have promptly changed the type of glaze as soon as their attention was directed to the lead hazard.

3. Second hand barrels and kegs of tight cooperage were sometimes a source of dangerous lead contamination during the war. You will recall the great scarcity of containers of every sort during the war years which lead to the reuse of almost anything that could be made tight. In one case the Food and Drug Administration caught a lot of olives that were very heavily contaminated with lead. This lead was found to have come from litharge which remained in barrels in which it had been shipped originally.

We now take leave of actual or potential hazards to public health and enter a region more properly described as quality control or flavor control. Let us dispose of a number of the lesser problems before discussing the major area of these problems. Nearly everything from this point on concerns inedibility due to unpleasant flavors. In this brief review the cases where the container manufacturer has a responsibility can only be barely mentioned.

1. The adhesive was at fault in one instance where glassine had been laminated to foil. The product wrapped in this laminate acquired an off flavor.

2. Animal glues are frequently treated with a bactericidal chemical during the course of their manufacture, for it is well known that a small amount of bacterial growth in the dilute glue will impair its adhesive properties.

Seemingly a purchasing agent who was not too well informed on his glues purchased a lot that was used to make set up paper boxes for candy. And the candy acquired a chlorphenol flavor.

3. There appears to be a continuing controversy among tea tasters about the flavors contributed by wet strength paper tea balls. The few tea ball paper people I have attempted to contact have not given out any information.

4. Printing inks of the wrong composition have been frequently cited as a source of off flavors, but not as a health hazard. One manufacturer reported that printing on tea cartons had been a problem for years until the development of odor free inks. (The following is in the nature of an aside: but inks for printing paper cups or containers for cottage cheese are often specified as "lactic acid proof." The problem here is to prevent the printing from "running.")

The remedy here, as in all other packaging problems, is to be certain that all suppliers are informed of the exact purpose to which their products are to be put. And then make proper tests before going into production.

5. One incident in the history of the tin can is old stuff, but is related here to show where obscure flavor changes may arise. Some years ago canned pears had an off-flavor that was ultimately traced to a sealing compound made from smoked sheet rubber. The first remedy was to change to unsmoked latex crepe. A more recent improvement has been the use of synthetic latex.

6. In the case of various films there has been some trouble in the past. This has arisen from the plasticizers that have been used. Some plasticizers have caused off odors to develop in packaged foods.

Long storage tests have been, and still are, necessary to detect flavor changes. Because packaging films are often in direct contact with foods, it is necessary to satisfy Food and Drug Administration or Bureau of Animal Industry of their acceptability of any new film. This acceptability can be secured only after a 2-year feeding test.

7. Here is an oddity: Not all flavor changes are due to substances imparted by the package. Cases are known where the flavor change was due to the subtraction of a flavoring from the food. One such case was reported where salad dressing had been packaged in a plastic container that absorbed one of the flavoring ingredients. The food became very undesirable.

The safe rule in dealing with plastics, whether rigid or flexible food packages, is to test everything for odor, flavor and toxicity.

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Having cleared away the lesser matters we now tackle some of the more obscure problems arising from flavor changes. Many of them arise from paper packages.

Many people may not be aware of the fact that paper may be re-used many times in the same general manner of re-using metals, rubber, and glass. Each of the industries using these materials has its special problems in the use of reclaimed scrap (or in more elegant language: secondary material). For example, the steel industry has been greatly concerned over the constant increase of copper in scrap iron and steel, for copper cannot be removed by any known practical method. So there is a constant build-up of copper in all our steels. It is causing many a worry, for there is not enough primary metal to supply all our needs and the need for economy through re-use is important. Other metals that are causing further concern to steel makers are molybdenum and nickel.

In somewhat the same manner, a comparable problem exists in paper manufacture. Old paper is used over and over, and frequently it carries in it certain substances that may not always be the most desirable for fabricating into food packages. One of the problems is foreign substances picked up from contents of packages where the old paper products are made with sizeable percentages of older scrap paper.

Another word of parenthetical explanation is desirable here. The paper package in its many forms is usually (though not always) the most economical package to use, provided it will provide the degree of protection needed. Hence the existence of a continuing effort on the part of packaging technologists to find suitable but cheaper packages made from paper. It is all a part and parcel of efforts to reduce the cost of distribution of food products and, hence, is highly commendable. With this brief preface we now take up paper packages in relation to the problem under discussion.

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The Institute of Paper Chemistry tells me that no infectious disease has ever been attributed to paper used in food packages. Examination of upwards of 4000 samples from 49 grades of paper for Coliform bacteria gave negative results.

A plentiful,—nay generous,—supply of pure clean water is important to the manufacturer of paper and paperboard.

Paperboard having a high bacterial count, even of saprophytic types, is likely to be of poor quality and such board is often the cause of off flavors in food stuffs packaged in this quality of board. The problem is said to arise not from the bacteria but from the conditions that existed whereby the bacterial count could multiply.

Some packaged foods have been known to taste rancid without having developed rancidity by reason of leakage of fat into paperboard where it quickly rancidified. The odor then permeated the food.

Fat containing foods present the greatest problems of off-flavors picked up from packages, e.g., cocoa powder, prepared cereals, even flour, and the like. These off-flavors are usually of three sorts: (a) normal paper odor; (b) chemicals used by the paper maker to restrain the growth of slime bacteria in paper mill streams; (c) chemicals or odors existing in the scrap paper itself.

Paperboard has a normal "paper odor" that may or may not be objectionable to a food processor. Some concerns insulate the board with a barrier in the form of a waxed paper liner. Some consider that a patent coating on virgin pulp is adequate. The better informed food processors believe that if the scrap paper is stored out of the weather their own problems are minimized. One food manufacturer specifies that all paper board for making his cartons must have been dried to less than 5 percent water content, and *kept dry!*

In the baking industry the efforts to reduce costs have lead to the use of coated paper cups or pans for baking purposes, or for wrapping bakery products so that icings, etc., will not stick. At oven temperatures such coatings may melt and hence must be harmless, odorless, and tasteless.

Where waxed paper is used, the paper itself must be odorless and the wax must not have been subjected to too high a heat. Also it must have been properly refined. Here the safe rule is to make absolutely sure that the supplier knows the exact purpose to which his waxed paper may be put. Then he can cooperate intelligently.

Now let us mention a few more case histories:

8. A chocolate manufacturer reports that he has had occasional odor and flavor troubles with packaging materials due to bactericidal chemicals used in paper making.

9. A regulatory official reports that phenolic compounds in paperboard have been known to render tea and cocoa unfit for consumption though no health problem was created.

10. Diphenyl-impregnated wraps on citrus fruits have been known to cause citrus to have an off-flavor.

11. One maker of hot melt coated papers for heat sealing purposes has long and successfully used a series of chemicals hitherto unknown in the coating industry without a single complaint. His success was built on long research, testing and feeding experiments. It can be done by those who have the will.

Off odor and off flavor in dried fruits have been picked up from the board container. The food processor remedied the complaint by the simple method of specifying that the interior surface of the cartons shall be lined or faced with a *first-use* sulphite board. This gave a sufficient barrier effect.

13. An obscure case of off-flavor in ice cream packaged in paper cups was once traced to the printing ink used to imprint the shipping container. The odor passed through the corrugated board, thence through the coated sulphite cups into the fat of the ice cream.

14. Off-flavor in ice cream has also been traced to stamping inks used to date or to identify the flavor in a paper container.

15. Mayonnaise once picked up a "medicinal" odor and flavor from newsboard in the cap liner. The mayonnaise manufacturer now uses a different liner and plays safe by specifying a wax coating 0.030 inches thick for a barrier.

16. In this case a strong musty odor has been traced to insecticides. But the investigation was very long and very expensive. The odor was identified as hexachlorbenzene present in the board at the rate of 1.1 ounce per ton (0.00342 percent). The odor was strong and persisted for a year with no diminution. The question was: where did so large a quantity of hexachlorbenzene come from?

The problem was solved by what was really an heroic method. First the board manufacturer called on all the nine manufacturers of hexachlorbenzene. He persuaded them to give him a list of all their customers (insecticide manufacturers). Then he drew a large circle around every such location and issued orders that not one pound of scrap paper should be purchased in that area. This was to avoid the possibility of getting any scrap paper that had been used for shipping hexachlorbenzene.

Next he alerted every key man in his plant to smell all incoming raw materials and all outgoing finished goods.

It solved the problem.

17. Once a frozen food packer complained that the board from which his cartons were made contained excessive acetone. This, the frozen food packer claimed, would combine with the sulphur normally present in leafy vegetables and give a very pronounced off-flavor.

Research by the container manufacturer revealed that there actually was a trace of acetone in his paper board. But he never was able to reproduce the off-odor by putting the same leafy vegetable into the cartons. The trouble only occurred at the plant of the frozen food packer.

Further research showed that the odor was due to Parathion, —an insecticide,—or to one of its close homologs—presumably absorbed by the vegetable from a spray or through the roots. The off-flavor and odor could be duplicated by soaking fresh vegetables for as little as 5 minutes in water containing 0.01 percent of Parathion.

The container had been blamed for the off-odor but in this case it was due to an agricultural chemical carried into the plant inside the food. No health hazard was involved. It was simply a problem of quality control where the food technologist had been unable to solve the problem.

## Summary

What does all this mean? What have we proved, if anything? I think it is fair to state that:

1. Container makers have their problems just as everybody else.

2. At present there are no problems or hazards to public health from agricultural chemicals or residues, where the U. S. A. container manufacturer has a direct responsibility.

3. The problems that do exist are quality control and flavor control problems.

4. Their solution requires the closest cooperation between the producer of packaged products and the supplier of packages.

5. If I may be permitted to put in a plug for packaging it is this: Food technologists must perforce become more familiar with the art and science of packaging, especially in the field of flexible packages.

# *If you have doubts about Ac'cent in your food*

(as one important food processor had)

He doubted that Ac'cent could improve the flavor of his beef stew. "Our beef stew is as good as we can make it commercially," he said. And his technical staff said the same.

# *You can try it on the consumer* (as he did)

He agreed to test Ac'cent and try it on the public. He ran two batches of beef stew, one with Ac'cent added, one without. He sent to 562 families a can from each batch, and asked them to compare the two.

# *And find out what he found out* (that people will like your food better when a little Ac'cent is added)

Out of the 1995 persons making up those 562 families, 1131 preferred the stew with Ac'cent! Here was the CONSUMER'S answer to this manufacturer's assertion that there was no practical way to improve his product.

*Ac'cent is not a flavoring, not a condiment. It adds no flavor, aroma or color of its own. It simply, but wonderfully, brings out—and holds —the* natural *flavors of foods. With Ac'cent, you use your own formulas: you prepare as usual—just add Ac'cent.*

*Ac'cent is a 99+% pure monosodium glutamate, derived from vegetable sources. A wholesome product of Nature. 100 and 200 lb. drums.*

Trade Mark "Ac'cent" Reg. U. S. Pat. Off.

**At no obligation to you,** we will welcome the opportunity to demonstrate what Ac'cent can do *in one of your own foods*—to pay the cost of a test run in your plant, including payment for the materials used!

Our food technologists will conduct the test. *You* be the judge. Wire or phone for full information.

# *Ac'cent® makes food flavors sing♪*

**Amino Products Division**
**International Minerals & Chemical Corp.**
**General Offices: 20 N. Wacker Drive**
**Chicago 6, Illinois**
**San Francisco: 214 Front Street**
**New York City: 61 Broadway**

Printed in U. S. A.

# Selected Abstracts

## ANALYTICAL METHODS

**1J. An extra sensitive reaction for the rancidity of fats.**

LEONT'EV, I. F. *Priroda, 36,* No. 7, 62 (1947); *Food Sci. Abst., 21,* 17 (1949).

To 2 mg. of fat in a test tube with a ground-glass stopper, 2 ml. of glacial acetic acid, 0.1 ml. of a 0.01% solution of Mohr's salt and 0.5 ml. of 0.01% solution of tetramethyl-p-phenylenediamine in acetone are added. The tube is placed in a boiling water bath and then shaken. A bluish violet colour near the bottom of the liquid indicates the presence of peroxide. Even if present in a dilution of 1 in 10 million or more, it can still be detected by this test.

**2J. Proximate method for detection and determination of eggs in food pastes.**

KIGER, J., AND BOIVIN, R. *Chimie Analyt., 30,* 172-9 (1948); *Analyst, 74,* 262-3 (1949).

The method of Farcey which depends upon the determination of N compounds soluble in hot and cold water, is applied to the examination of pastes made with eggs, with egg-yolk powder, and with whole egg powder. The results show that the method does not lead to positive conclusions. The method relies on 2 determinations: determination of soluble N compounds precipitable by alcohol and determination of ether-extractable matter.

**3J. A simple electrical meter for estimating the moisture content of grain.**

RASMUSSEN, H. E., AND ANDERSON, J. A. *Canadian J. Res., 27F,* 249-52 (1949).

A simple electrical meter has been devised for estimating the moisture content of grain. It accommodates a 190 g. sample which forms the dielectric of a condenser in the plate tuning circuit of a triode crystal oscillator. An increase in the dielectric constant due to moisture in the sample is compensated for by removing capacity from a variable condenser attached to the dial of the instrument. A piezolectric plate determines the frequency at which the triode section of the tube will oscillate, and this state is indicated by a change in the shadow angle of the indicator section of the same tube. The meter has been calibrated with 159 samples of Canadian hard red spring wheat; the standard error of estimation was found to be 0.36 over the range from 10 to 17% moisture.

**4J. Photometric determination of alpha- and beta-amylase in flour.**

HOSKAM, E. G. *Biochim. Biophys. Acta., 1,* 419-27 (1947); *Analyst, 74,* 264-5 (1949).

Since the so-called "sticky crumb" of rye bread is attributed to the liquefying and dextrinizing action of α-amylase, a method is required to determine variable amounts of α-amylase in the presence of β-amylase. The saccharogenic action of α-amylase is less pronounced than its liquefying and dextrinizing power, whereas the action of β-amylase is mainly saccharogenic, although it appears to have some dextrinizing properties. Only if the α-amylase content is relatively large does it serve as a criterion of the quality of the flour. The extinction of an iodine-starch or iodine-dextrin solution is directly proportional to the starch or dextrin concentration for all wavelengths. Erythrodextrin, the end-product of β-amylolytic breakdown of starch, can be used as a specific substrate for the determination of α-amylase and the determination can be made in a simple way by measuring the extinction after addition of iodine solution. By isolating solid erythrodextrin the separate actions of α and β-amylase on this substrate could be studied, and it was established that the subsequent attack on erythrodextrin is governed only by α-amylase, at least during the first part of the reaction. By using a buffered solubilized starch solution instead of erythrodextrin solution, it was shown that the amount of starch broken down is an additive function of the amounts of α and β-amylase present. The amount of β-amylase can thus be found by calculation.

**5J. Determination of vitamin $B_1$ in vegetable tissues by means of the thiochrome method.**

ANTONIANI, C., AND FEDERICO, L. *Ann. Sper. Agr., 2,* 51 (1948); *Food Sci. Abst., 21,* 35 (1949).

When the thiochrome method is used to estimate vitamin $B_1$ in vegetables, extraneous fluorescences (particularly red) may interfere with the determination. This can be eliminated by preliminary treatment of the fresh vegetable tissue which is first dehydrated with anhydrous sodium sulphate and then completely extracted with anhydrous sulphuric ether.

**6J. The fluorimetric estimation of riboflavin in foodstuffs and other biological material.**

KODICEK, E., AND WANG, Y. L. *Biochem. J., 44,* 340-3 (1949).

A modification of a fluorimetric method for the estimation of riboflavin has been described. It estimates directly the fluorescence of riboflavin by using a sensitive photocell-galvanometer circuit without recourse to adsorption. Washing of the extracts with chloroform and oxidation by potassium permanganate and hydrogen peroxide reduces the interference by unspecific fluorescent substances. The reduction of riboflavin by sodium dithionite has been used to obtain the value of the blank.

**7J. The fluorimetric estimation of nicotinamide in biological materials.**

CHAUDHURI, D. K., AND KODICEK, E. *Biochem. J., 44,* 343-8 (1949).

A quantitative method for the estimation of nicotinamide has been developed, based on the formation of a fluorescent compound from nicotinamide on treatment with cyanogen bromide under specified conditions. The method eliminates possible interference by other compounds giving a similar fluorescence under the conditions of the test by the use of acid and alkaline pre-treatment and of a special blank. It estimates the total nicotinamide content, including the free and bound forms. The procedure gives specific and reproducible results for biological materials and for cereals, and the results agree well with the reported microbiological values. Practically all the vitamin in rat organs and muscles seems to be present in the form of the amide, bound or free. In bran no nicotinamide could be detected before or after digestion. It is assumed that the breakdown product of the 'precursor' of nicotinic acid present in bran is the free acid and not the amide. Yeast and wheat germ seem to contain about 50% of the vitamin present in the amide form, bound or free.

## BIOLOGICAL SCIENCES

### MICROBIOLOGY

**8J. Canine salmonellosis.**

KINTNER, L. *Vet. Med., 64,* 396-8 (1949).

Salmonellosis is more common in dogs than has been thought heretofore. Salmonella organisms are relatively common in substances that frequently contaminate the ration of dogs, and salmonellosis organisms can cause serious illness in dogs. However, it was not possible to cause illness by direct feeding of the organisms to healthy mature dogs.

### NUTRITION

**9J. Fluorine in foods.**

MCCLURE, F. J. *Pub. Health Rep., 64,* 1061-74 (1949).

A survey of recent analytical data for fluorine in foods has been compiled. The majority of foods found in the average diet contain from 0.2-0.3 p.p.m. or less fluorine in the food as consumed. Tea and seafoods are notable exceptions, the former containing upwards of 75 to 100 p.p.m. fluorine in the dry tea, whereas seafoods may contain 5-15 p.p.m. fluorine. Cow's milk contains about 0.1-0.2 p.p.m. flourine. Fluoride added to the cow's ration or drinking water has no influence on milk-fluoride. Although the data are limited, it appears that natural food-borne fluorine is largely available for body assimilation. Exclusive of drinking water, the average diet appears to provide 0.2-0.3 mg. of fluorine daily. However, it has been observed that an additional intake of fluorine during formative tooth life, via drinking water containing 1.00 p.p.m. or slightly more fluorine, is a distinct dental health advantage. The possibility of a direct dietary flouride supplement where the drinking water does not provide a dental optimum quantity of fluorine is worthy of consideration.

(Continued on page 4)

# News of the Institute

## TENTATIVE PROGRAM — 1950 CONFERENCE
## INSTITUTE OF FOOD TECHNOLOGISTS

### Sunday, May 21, 1950

MORNING
Council Meeting, 10:00 a.m.-5:00 p.m.

EVENING
Social Hours, 5:00-7:00
Committee Meetings, 7:30-9:30
Chemical Residues in Foods, Pectin Standardization, Citrus Products, etc.

### Monday, May 22

MORNING
General Session, 9:30-12:00
Welcome Address, Mayor Martin H. Kennelley
Presidential Address, Carl R. Fellers
Other Speakers
Ernest H. Volweiler, Executive Vice President, Abbott Laboratories; President, American Chemical Society
Guy E. Reed, Vice President, Harris Trust & Savings Bank, Chicago
Henry T. Heald, President, Illinois Institute of Technology

AFTERNOON
Babcock Award Luncheon, 12:15-1:45
Concurrent Sessions, 2:00-5:00
A. Symposium: Chemical Agents and Residues in Food (6 papers)
B. Industrial and Production: Cereal Technology (6 papers)
C. Research Investigations: Divided into two Divisions (6 papers each)

EVENING
Mixer, 8:00-until

### Tuesday, May 23

MORNING
Section Officers Breakfast, 7:30-8:45
Concurrent Sessions, 9:00-12:00
A. Symposium: Fish and Fishery By-Products (6 papers)
B. Industrial and Production: Canning Technology (6 papers)
C. Research Investigations: Two Divisions (6 papers each)

AFTERNOON
Executives Luncheon, 12:15-2:15
Speakers:
Dr. Leverett Lyon, Chief Executive Officer, The Chicago Association of Commerce and Industry
Mr. Allan B. Kline, President, American Farm Bureau Federation
Visit Exhibitors and Personal Conferences, 2:15-5:00

EVENING
Banquet—Appert Medal Presentation, 7:00

### Wednesday, May 24

MORNING
Food Technology Editorial Board Breakfast, 7:30-8:50
Concurrent Sessions, 9:00-12:00
A. Symposium: By-Products of the Packing House Industry (6 papers)
B. Industrial and Production: Candy Technology (6 papers)
C. Research Investigations: Two Divisions (6 papers each)

AFTERNOON
I. F. T. Business Meeting and Luncheon, 12:10-1:50
Concurrent Sessions, 2:00-5:00
A. Discussion Group: Frozen Foods Committee
B. Industrial and Production: Sanitation in the Food Industry (6 papers)
C. Research Investigations: Two Divisions (6 papers each)

EVENING
Dinner and Entertainment, Marine Dining Room (tentative)

### Thursday, May 25

MORNING
"Guinea Pig" Breakfast, 7:30-8:50
A. Symposium: Military Subsistence of the Future

AFTERNOON
Plant Trips, From 1:00

### Friday, May 26

MORNING
Plant Trips, 8:00-12:00

## MEETING OF EXECUTIVE COMMITTEE

Proceedings of meeting of the Executive Committee of the Council held at the LaSalle Hotel October 30, 1949, at the call of the President.

Present: Dr. Carl R. Fellers, President
Dr. Paul F. Sharp, President-Elect
Dr. B. S. Clark
Mr. Ray Wakefield
Dr. George F. Stewart
Mr. Walter D. Pheteplace

The following attended the meeting for the purpose of rendering reports and/or advising the Council:

Dr. Lloyd A. Hall
Col. Rohland A. Isker
Mr. E. S. Stateler
Mr. C. L. Smith
Col. Charles S. Lawrence, Executive Secretary, Recorder

The meeting was called to order at 10:30 A. M., with Dr. Fellers presiding.

1. Dr. Fellers made a brief report of the status of the Institute as follows:

The affairs of the Institute have been going smoothly since the San Francisco meeting. The transfer of the Secretary's office from Amherst, Mass. to Chicago, Ill., has been about completed. Total membership to date about 2950, of which approximately 75% are members and 25% affiliates.

2. It was moved, seconded and carried that the procedure for payment of dues by new members be as follows: that the payment of the first year's dues accompany the application, the individual taking the application to examine the qualifications of the applicant and

(Continued on page 10 following technical papers)